

OUTCOME PREDICTION AND RISK CLASSIFICATION IN CHILDHOOD
LEUKEMIA

5 This application claims the benefit of U.S. Provisional Applications
Serial Nos. 60/432,064; 60/432,077; and 60/432,078; all of which were filed
December 6, 2002; and U.S. Provisional Applications Serial Nos. 60/510,904
and 60/510,968, both of which were filed October 14, 2003; and a U.S.
Provisional Application entitled "Outcome Prediction in Childhood Leukemia"
10 filed on even date herewith. These provisional applications are incorporated
herein by reference in their entireties.

STATEMENT OF GOVERNMENT RIGHTS

 This invention was made with government support under a grant from
15 the National Institutes of Health (National Cancer Institute), Grant No. NIH
NCI U01 CA88361; and under a contract from the Department of Energy,
Contract No. DE-AC04-94AL85000. The U.S. Government has certain rights
in this invention.

20 BACKGROUND OF THE INVENTION

 Leukemia is the most common childhood malignancy in the United
States. Approximately 3,500 cases of acute leukemia are diagnosed each year
in the U.S. in children less than 20 years of age. The large majority (>70%) of
these cases are acute lymphoblastic leukemias (ALL) and the remainder acute
25 myeloid leukemias (AML). The outcome for children with ALL has improved
dramatically over the past three decades, but despite significant progress in
treatment, 25% of children with ALL develop recurrent disease. Conversely,
another 25% of children who now receive dose intensification are likely "over-
treated" and may well be cured using less intensive regimens resulting in fewer
30 toxicities and long term side effects. Thus, a major challenge for the treatment
of children with ALL in the next decade is to improve and refine ALL diagnosis
and risk classification schemes in order to precisely tailor therapeutic
approaches to the biology of the tumor and the genotype of the host.

Leukemia in the first 12 months of life (referred to as infant leukemia) is extremely rare in the United States, with about 150 infants diagnosed each year. There are several clinical and genetic factors that distinguish infant leukemia from acute leukemias that occur in older children. First, while the percentage of acute lymphoblastic leukemia (ALL) cases is far more frequent (approximately five times) than acute myeloid leukemia in children from ages 1-15 years, the frequency of ALL and AML in infants less than one year of age is approximately equivalent. Secondly, in contrast to the extensive heterogeneity in cytogenetic abnormalities and chromosomal rearrangements in older children with ALL and AML, nearly 60% of acute leukemias in infants have chromosomal rearrangements involving the MLL gene (for Mixed Lineage Leukemia) on chromosome 11q23. MLL translocations characterize a subset of human acute leukemias with a decidedly unfavorable prognosis. Current estimates suggest that about 60% of infants with AML and about 80% of infants with ALL have a chromosomal rearrangement involving MLL abnormality in their leukemia cells. Whether hematopoietic cells in infants are more likely to undergo chromosomal rearrangements involving 11q13 or whether this 11q13 rearrangement reflects a unique environmental exposure or genetic susceptibility remains to be determined.

The modern classification of acute leukemias in children and adults relies on morphologic and cytochemical features that may be useful in distinguishing AML from ALL, changes in the expression of cell surface antigens as a precursor cell differentiates, and the presence of specific recurrent cytogenetic or chromosomal rearrangements in leukemic cells. Using monoclonal antibodies, cell surface antigens (called clusters of differentiation (CD)) can be identified in cell populations; leukemias can be accurately classified by this means (immunophenotyping). By immunophenotyping, it is possible to classify ALL into the major categories of "common - CD10+ B-cell precursor" (around 50%), "pre-B" (around 25%), "T" (around 15%), "null" (around 9%) and "B" cell ALL (around 1%). All forms other than T-ALL are considered to be derived from some stage of B-precursor cell, and "null" ALL is sometimes referred to as "early B-precursor" ALL.

Current risk classification schemes for ALL in children from 1-18 years of age use clinical and laboratory parameters such as patient age, initial white blood cell count, and the presence of specific ALL-associated cytogenetic abnormalities to stratify patients into "low," "standard," "high," and "very high" risk categories. National Cancer Institute (NCI) risk criteria are first applied to all children with ALL, dividing them into "NCI standard risk" (age 1.00-9.99 years, WBC < 50,000) and "NCI high risk" (age > 10 years, WBC > 50,000) based on age and initial white blood cell count (WBC) at disease presentation. In addition to these general NCI risk criteria, classic cytogenetic analysis and molecular genetic detection of frequently recurring cytogenetic abnormalities have been used to stratify ALL patients more precisely into "low," "standard," "high," and "very high" risk categories. Fig. 1 shows the 4-year event free survival (EFS) projected for each of these groups.

These chromosomal aberrations primarily involve structural rearrangements (translocations) or numerical imbalances (hyperdiploidy - now assessed as specific chromosome trisomies, or hypodiploidy). Table 1 shows recurrent ALL genetic subtypes, their frequencies and their risk categorization.

Table 1: Recurrent Genetic Subtypes of B and T Cell ALL

Subtype	Associated Genetic Abnormalities	Frequency in Children	Risk Category
B-Precursor ALL	Hyperdiploid DNA Content; Trisomies of Chromosomes 4, 10, 17	25% of B Precursor Cases	Low
	t(12;21)(p13;q22): TEL/AML1	28% of B Precursor Cases	Low
	11q23/MLL Rearrangements; particularly t(4;11)(q21;q23)	4% of B Precursor Cases; >80% of Infant ALL	
	t(1;19)9q23;p13 – E2A/PBX1	6% of B Precursor Cases	High
	t(9;22)(q34;q11): BCR/ABL	2% of B Precursor Cases	High
	Hypodiploidy	Relatively Rare	Very High
B-ALL	t(8;14)(q24;q32) – IgH/MYC	5% of all B lineage ALL cases	Very High
T-ALL	Numerous translocations involving the TCR $\alpha\beta$ (7q35) or TCR $\gamma\delta$ (14q11) loci	7% of ALL cases	High
			Not Clearly Defined

The rate of disappearance of both B precursor and T ALL leukemic cells during induction chemotherapy (assessed morphologically or by other quantitative measures of residual disease) has also been used as an assessment of early therapeutic response and as a means of targeting children for therapeutic intensification (Gruhn et al., Leukemia 12:675-681, 1998; Foroni et al., Br. J. Haematol. 105:7-24, 1999; van Dongen et al., Lancet 352:1731-1738, 1998; Cavé et al., N. Engl. J. Med. 339:591-598, 1998; Coustan-Smith et al., Lancet 351:550-554, 1998; Chessells et al., Lancet 343:143-148, 1995; Nachman et al., N. Engl. J. Med. 338:1663-1671, 1998).

Children with "low risk" disease (22% of all B precursor ALL cases) are defined as having standard NCI risk criteria, the presence of low risk cytogenetic abnormalities (t(12;21)/TEL;AML1 or trisomies of chromosomes 4 and 10), and a rapid early clearance of bone marrow blasts during induction chemotherapy. Children with "standard risk" disease (50% of ALL cases) are NCI standard risk without "low risk" or unfavorable cytogenetic features, or, are children with low risk cytogenetic features who have NCI high risk criteria or slow clearance of blasts during induction. Although therapeutic intensification has yielded significant improvements in outcome in the low and standard risk groups of ALL, it is likely that a significant number of these children are currently "over-treated" and could be cured with less intensive regimens resulting in fewer toxicities and long term side effects. Conversely, a significant number of children even in these good risk categories still relapse and a precise means to prospectively identify them has remained elusive. Nearly 30% of children with ALL have "high" or "very high" risk disease, defined by NCI high risk criteria and the presence of specific cytogenetic abnormalities (such as t(1;19), t(9;22) or hypodiploidy) (Table 1); again, precise measures to distinguish children more prone to relapse in this heterogeneous group have not been established.

Despite these efforts, current diagnosis and risk classification schemes remain imprecise. Children with ALL more prone to relapse who require more intensive approaches and children with low risk disease who could be cured with less intensive therapies are not adequately predicted by current classification schemes and are distributed among all currently defined risk groups. Although pre-treatment clinical and tumor genetic stratification of patients has generally improved outcomes by optimizing therapy, variability in clinical course continues to exist among individuals within a single risk group and even among those with similar prognostic features. In fact, the most significant prognostic factors in childhood ALL explain no more than

4% of the variability in prognosis, suggesting that yet undiscovered molecular mechanisms dictate clinical behavior (Donadieu et al., *Br J Haematol*, 102:729-739, 1998). A precise means to prospectively identify such children has remained elusive.

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SUMMARY OF THE INVENTION

The present invention is directed to methods for outcome prediction and risk classification in childhood leukemia. In one embodiment, the invention provides a method for classifying leukemia in a patient that includes obtaining a biological sample from a patient; determining the expression level for a selected gene product to yield an observed gene expression level; and comparing the observed gene expression level for the selected gene product to a control gene expression level. The control gene expression level can be the expression level observed for the gene product in a control sample, or a predetermined expression level for the gene product. An observed expression level that differs from the control gene expression level is indicative of a disease classification. In another aspect, the method can include determining a gene expression profile for selected gene products in the biological sample to yield an observed gene expression profile; and comparing the observed gene expression profile for the selected gene products to a control gene expression profile for the selected gene products that correlates with a disease classification; wherein a similarity between the observed gene expression profile and the control gene expression profile is indicative of the disease classification.

The disease classification can be, for example, a classification based on predicted outcome (remission vs therapeutic failure); a classification based on karyotype; a classification based on leukemia subtype; or a classification based on disease etiology. Where the classification is based on disease outcome, the observed gene product is preferably a gene such as OPAL1, G1, G2, FYN binding protein, PBK1 or any of the genes listed in Table 42.

A novel gene, referred to herein as OPAL1, has been found to be strongly predictive of outcome in childhood leukemia, and presents new opportunities for better diagnosis, risk classification and better therapeutic options. Thus, in another embodiment, the invention includes a polynucleotide that encodes OPAL1 and variations thereof, the putative protein gene product of OPAL1 and variations thereof,

and an antibody that binds to OPAL1, as well as host cells and vectors that include OPAL1.

The invention further provides for a method for predicting therapeutic outcome in a leukemia patient that includes obtaining a biological sample from a patient; determining the expression level for a selected gene product associated with outcome to yield an observed gene expression level; and comparing the observed gene expression level for the selected gene product to a control gene expression level for the selected gene product. The control gene expression level for the selected gene product can include the gene expression level for the selected gene product observed in a control sample, or a predetermined gene expression level for the selected gene product; wherein an observed expression level that is different from the control gene expression level for the selected gene product is indicative of predicted remission. Preferably, the selected gene product is OPAL1. Optionally, the method further comprises determining the expression level for another gene product, such as G1 or G2, and comparing in a similar fashion the observed gene expression level for the second gene product with a control gene expression level for that gene product, wherein an observed expression level for the second gene product that is different from the control gene expression level for that gene product is further indicative of predicted remission.

The invention further includes a method for detecting an OPAL1 polynucleotide in a biological sample which includes contacting the sample with an OPAL1 polynucleotide, or its complement, under conditions in which the polynucleotide selectively hybridizes to an OPAL1 gene; detecting hybridization of the polynucleotide to the OPAL1 gene in the sample. Likewise, the invention provides a method for detecting the OPAL1 protein in a biological sample that includes contacting the sample with an OPAL1 antibody under conditions in which the antibody selectively binds to an OPAL1 protein; and detecting the binding of the antibody to the OPAL1 protein in the sample. Pharmaceutical compositions including an therapeutic agent that includes an OPAL1 polynucleotide, polypeptide or antibody, together with a pharmaceutically acceptable carrier, are also included.

The invention further includes a method for treating leukemia comprising administering to a leukemia patient a therapeutic agent that modulates the amount or activity of the polypeptide associated with outcome. Preferably, the therapeutic agent increases the amount or activity of OPAL1.

Also provided by the invention is an *in vitro* method for screening a compound useful for treating leukemia. The invention further provides an *in vivo* method for evaluating a compound for use in treating leukemia. The candidate compounds are evaluated for their effect on the expression level(s) of one or more gene products associated with outcome in leukemia patients. Preferably, the gene product whose expression level is evaluated is the product of an OPAL1, G1, G2, FYN binding protein or PBK1 gene, or any of the genes listed in Table 42. More preferably, the gene product is a product of the OPAL1 gene.

BRIEF DESCRIPTION OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawings will be provided by the Office upon request and payment of the necessary fee.

Figure 1 shows the 4 year event free survival (EFS) projected for NCI risk categories.

Figure 2 shows the nucleotide sequences and amino acid sequences for the coding regions of two distinct OPAL1/G0 splice forms. Fig. 2A shows nucleotide sequence (SEQ ID NO:1) and amino acid sequence (SEQ ID NO:2) for the OPAL1/G0 splice form incorporation exon 1; and Fig. 2B shows nucleotide sequence (SEQ ID NO:3) and amino acid sequence (SEQ ID NO:4) for the OPAL1/G0 splice form incorporation exon 1a. Exons 1 and 1a are highlighted by italicized bold print. Numbers to the right indicate nucleotide and amino acid positions. Fig. 2C shows the sequence (SEQ ID NO:16) for the full length cDNA of OPAL1. The first exon (exon 1 in this example) is underlined. The start and end positions for the exons in the cDNA and reference sequence (GenBank accession NT_030059.11) are as follows: exon 1, bases 1 to 171 (23284530 to 23284700), exon 2, bases 172 to 274 (23306276 to 23306378), exon 3, bases 275 to 436 (23318176 to 23318337) and exon 4, bases 437 to 4008 (23320878 to 23324547). The polyadenylation signal (position 4086 to 4091) is shown in bold and italics.

Figure 3 shows a bootstrap statistical analysis of gene list stability.

Figure 4 is a Bayesian tree associated with outcome in ALL.

Figure 5 is schematic drawing of the structure of OPAL1/G0.

Figure 6 is a topographic map produced using *VxInsight* showing 9 novel biologic clusters of ALL (2 distinct T ALL clusters (S1 and S2) and 7 distinct B precursor ALL clusters (A, B, C, X, Y, Z)) each with distinguishing gene expression profiles.

Figure 7 shows a gene list comparison. Principal Component Analysis (PCA and the *VxInsight* clustering program (ANOVA) were employed to identify genes that determined T-cell leukemia cases. The gene lists are compared with those derived from the different feature selection methods used by Yeoh et al. (Cancer Cell, 1:133-143, 2002) for T-cell classification. The yellow color represents overlap between the lists derived by PCA and the T-ALL characterizing gene lists; the cyan represents overlap between the ANOVA and the T-ALL characterizing gene lists. The green pattern represents genes that are shared by all the lists.

Figure 8 shows a gene list comparison. Bayesian Networks were employed to identify genes that determined the gene expression patterns across the different translocations. The gene lists were compared with those derived using chi square analysis by Yeoh et al. (Cancer Cell, 1:133-143, 2002) for ALL classification. The colored cells represent overlap between the lists derived by Bayesian nets and the ALL characterizing gene lists from Yeoh et al. (Cancer Cell, 1:133-143, 2002).

Figure 9 shows Principal Component Analysis of the infant gene expression data. Principal Component Analysis (PCA) projections are used to compare the ALL/AML partition, the MLL/Non-MLL partition, and the *VxInsight* partition of the infant gene expression data. The three by three grid of plots in this figure allows this comparison by using the same PCA projections with different colors for the different partitions. Each row of the grid shows a different partition and each column shows a different PCA projection. The ALL/AML partition is shown in the first row of the figure using light purple for ALL and dark purple for AML. The three plots in this row give two-dimensional projections of the data onto the first three principal components. Since there are three such projections there are three plots (from left to right): PC 1 vs. PC 2, PC 2 vs. PC 3, and PC 1 vs. PC 3. This scheme is repeated for the remaining two partitions. Specifically, the MLL/Non-MLL partition is shown using orange and dark green in the second row, and the *VxInsight* partition is shown using red, green, and blue in the last row. This grid enables both visualization of the data (by examining the rows) and comparison of the partitions (by examining the columns).

Figure 10 shows results of the graphic directed algorithm applied to the infant dataset. The *VxInsight* program constructs a mountain terrain over the clusters such that the height of each mountain represents the number of elements in the cluster under the mountain. Top left: this force-directed clustering algorithm partitions the infant data into three clusters labeled A, B, and C. Top right: *VxInsight* terrain map showing the distribution of the leukemia types across the clusters. ALL cases are shown in white and AML are shown in green. Bottom left: *VxInsight* terrain map showing the distribution of MLL cases (shown in blue) across the clusters.

Figure 11 shows hierarchical clustering of the 126 infant leukemia samples using the "cluster-characterizing" gene sets. The rows represent genes that distinguish between the *VxInsight* clusters from Figure 2 (n=150). Genes were selected by ANOVA as being the 0.1% top discriminating between each one of the clusters and the rest of the cases. Each gene is normalized across all 126 cases and the relative expression is depicted in the heat map by color, as shown in the expression scale in the bottom of the figure. The patient-to-patient distance was computed using Pearson's correlation coefficient in the Genespring program (Silicon Genetics). The columns in the dendrogram represent patients as clustered by their gene expression. The correlation between these three resultant clusters and the *VxInsight* clusters is higher than 90%.

Figure 12 shows gene expression for various hematopoietic stem cell antigens in the infant leukemia data set. Fig. 12A is a gene expression "heat map" of selected HOX genes and hematopoietic stem cell antigens. The columns represent genes, while the rows represent patients organized by their *VxInsight* cluster membership A, B or C (see Fig. 10). The gene expression signals of 31 genes from the 26 leukemia patients were normalized relative to the median signal for each gene. The color characterizes the relative expression from the median. Red represents expression greater than the median, black is equal to the median and green is less than the median. Fig. 12B shows HOX genes median expression across the *VxInsight* clusters of the infant leukemia data set. The red, blue and black bars represent the median of expression of each HOX family gene across all the cases in *VxInsight* clusters A, B and C, respectively.

Figure 13 shows a *VxInsight* patient map showing the distribution of *MLL* cases across the clusters derived from gene expression similarities. Top left: Magnification of the cluster A (15 ALL/ 5 AML cases), characterized by a "stem cell-

like" gene expression pattern. Top right: cluster B, mainly ALL (51 ALL/1 AML cases). Bottom left: cluster C, mainly AML (12 ALL/42 AML cases).

Figure 14 shows Affymetrix gene expression signal for the FMS-related tyrosine kinase 3 (FLT3) gene across the different *MLL* translocations. The error bar represents the standard error of the mean. Other *MLL* translocations include t(7;11), t(X;11) and t(11;11).

Figure 15 shows genes that characterize the t(4;11) translocation in A vs. B, derived from the *VxInsight* clustering program using ANOVA. The red color represents genes that have higher expression in the t(4;11) cases in *VxInsight* cluster A against the t(4;11) cases in *VxInsight* cluster B.

Figure 16 shows genes that characterize each one of the *MLL* translocations (derived from Bayesian Networks Analysis). The highlighted genes represent possible therapeutic targets.

Figure 17 shows genes that characterize each the t(4;11) translocation and the *MLL* translocations, derived from Bayesian Networks Analysis, Support Vector Machines (SVM), Fuzzy logics and Discriminant Analysis.

Figure 18 shows genes that characterize the t(4;11) translocation (left column) and the *MLL* translocations (right column), derived from the *VxInsight* clustering program using ANOVA. The red color represents genes that have higher expression in the t(4;11) cases against the rest of the cases or the *MLL* cases against the rest.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Gene expression profiling can provide insights into disease etiology and genetic progression, and can also provide tools for more comprehensive molecular diagnosis and therapeutic targeting. The biologic clusters and associated gene profiles identified herein are useful for refined molecular classification of acute leukemias as well as improved risk assessment and classification. In addition, the invention has identified numerous genes, including but not limited to the novel gene OPAL1 (also referred to herein as "G0"), G protein $\beta 2$, related sequence 1 (also referred to herein as "G1"); IL-10 Receptor alpha (also referred to herein as "G2"), FYN-binding protein and PBK1, and the genes listed in Table 42 that are, alone or in combination, strongly predictive of outcome in pediatric ALL. The genes identified herein, and the proteins

they encode, can be used to refine risk classification and diagnostics, to make outcome predictions and improve prognostics, and to serve as therapeutic targets in infant leukemia and pediatric ALL.

"Gene expression" as the term is used herein refers to the production of a biological product encoded by a nucleic acid sequence, such as a gene sequence. This biological product, referred to herein as a "gene product," may be a nucleic acid or a polypeptide. The nucleic acid is typically an RNA molecule which is produced as a transcript from the gene sequence. The RNA molecule can be any type of RNA molecule, whether either before (e.g., precursor RNA) or after (e.g., mRNA) post-transcriptional processing. cDNA prepared from the mRNA of a sample is also considered a gene product. The polypeptide gene product is a peptide or protein that is encoded by the coding region of the gene, and is produced during the process of translation of the mRNA.

The term "gene expression level" refers to a measure of a gene product(s) of the gene and typically refers to the relative or absolute amount or activity of the gene product.

The term "gene expression profile" as used herein is defined as the expression level of two or more genes. Typically a gene expression profile includes expression levels for the products of multiple genes in given sample, up to 13,000 in the experiments described herein, preferably determined using an oligonucleotide microarray.

Unless otherwise specified, "a," "an," "the," and "at least one" are used interchangeably and mean one or more than one.

Diagnosis, Prognosis and Risk Classification

Current parameters used for diagnosis, prognosis and risk classification in pediatric ALL are related to clinical data, cytogenetics and response to treatment. They include age and white blood count, cytogenetics, the presence or absence of minimal residual disease (MRD), and a morphological assessment of early response (measured as slow or rapid early therapeutic response). As noted above however, these parameters are not always well correlated with outcome, nor are they precisely predictive at diagnosis.

The present invention provides an improved method for identifying and/or classifying acute leukemias. Expression levels are determined for one or more genes

associated with outcome, risk assessment or classification, karyotype (e.g., MLL translocation) or subtype (e.g., ALL vs. AML; pre-B ALL vs. T-ALL. Genes that are particularly relevant for diagnosis, prognosis and risk classification according to the invention include those described in the tables and figures herein. The gene expression levels for the gene(s) of interest in a biological sample from a patient diagnosed with or suspected of having an acute leukemia are compared to gene expression levels observed for a control sample, or with a predetermined gene expression level. Observed expression levels that are higher or lower than the expression levels observed for the gene(s) of interest in the control sample or that are higher or lower than the predetermined expression levels for the gene(s) of interest provide information about the acute leukemia that facilitates diagnosis, prognosis, and/or risk classification and can aid in treatment decisions. When the expression levels of multiple genes are assessed for a single biological sample, a gene expression profile is produced.

In one aspect, the invention provides genes and gene expression profiles that are correlated with outcome (i.e., complete continuous remission vs. therapeutic failure) in infant leukemia and/or in pediatric ALL. Assessment of one or more of these genes according to the invention can be integrated into revised risk classification schemes, therapeutic targeting and clinical trial design. In one embodiment, the expression levels of a particular gene are measured, and that measurement is used, either alone or with other parameters, to assign the patient to a particular risk category. The invention identifies several genes whose expression levels, either alone or in combination, are associated with outcome, including but not limited to OPAL1/G0, G1, G2, PBK1 (Affymetrix accession no. 39418_at, DKFZP564M182 protein; GenBank No. AJ007398); FYN-binding protein (Affymetrix accession no. 41819_at, FYB-120/130; GenBank No. AF001862; da Silva, Proc. Nat'l. Acad. Sci. USA 94(14):7493-7498 (1997)); and the genes listed in Table 42. Some of these genes (e.g., OPAL1/G0) exhibit a positive association between expression level and outcome. For these genes, expression levels above a predetermined threshold level (or higher than that exhibited by a control sample) is predictive of a positive outcome. Our data suggests that direct measurement of the expression level of OPAL1/G0, optionally in conjunction with G1 and/or G2, can be used in refining risk classification and outcome prediction in pediatric ALL. In particular, it is expected such measurements can be used to refine risk classification in children who are

otherwise classified as having low risk ALL, as well as to precisely identify children with high risk ALL who could be cured with less intensive therapies.

OPAL1/G0, in particular, is a very strong predictor for outcome. Our data suggest that OPAL1/G0 (alone and/or together with G1 and/or G2) may prove to be the dominant predictor for outcome in infant leukemia or pediatric ALL, more powerful than the current risk stratification standards of age and white blood count. OPAL1/G0 tends to be expressed at lower frequencies and lower overall levels in ALL cases with cytogenetic abnormalities associated with a poorer prognosis (such as t(9;22) and t(4;11)). Indeed, regardless of risk classification, cytogenetics or biological group, roughly the same outcome statistics are seen based upon the expression level of OPAL1/G0.

We found that higher OPAL1 expression distinguished ALL cases with good (OPAL1 high: 87% long term remission) versus poor outcome (OPAL1 low: 32% long term remission) in a statistically designed, retrospective pediatric ALL case control study (detailed below). Low OPAL1 was associated with induction failure ($p=.0036$) while high OPAL1 was associated with long term event free survival ($p=.02$), particularly in males ($p=.0004$). OPAL1 was more frequently expressed at higher levels in cases with t(12;21), normal karyotype, and hyperdiploidy (better prognosis karyotypes) compared to t(1;19) or t(9;22) (poorer prognosis karyotypes). 86% of ALL cases with t(12;21) and high OPAL1 achieved long term remission in contrast to only 35% of t(12;21) cases with low OPAL1, suggesting that OPAL1 may be useful in prospectively identifying children who might benefit from further intensification. In ALL cases classified as high risk by the NCI criteria, 87% of those that exhibited high OPAL1 levels actually achieved long term remission, compared an overall long term remission outcome of 44% in this cohort. OPAL1 was also highly predictive of a favorable outcome in T ALL ($p=.02$) and a similar trend was observed in a distinct infant ALL data set (see below). Thus, high OPAL1 levels are expected to be associated with long term remissions on standard, less intensive therapies, and conversely low OPAL1 levels, even in otherwise low risk ALL patients defined by current risk classification schemes, can identify children who require therapeutic intensification for cure.

For genes such as PBK1 whose expression levels are inversely correlated with outcome, observed expression levels above a predetermined threshold level (or higher than those observed in a control sample) are useful for classifying a patient into a

higher risk category due to the predicted unfavorable outcome. Expression levels for multiple genes can be measured. For example, if normalized expression levels for OPAL1/G0, G1 and G2 are all high, a favorable outcome can be predicted with greater certainty.

5 The expression levels of multiple (two or more) genes in one or more lists of genes associated with outcome can be measured, and those measurements are used, either alone or with other parameters, to assign the patient to a particular risk category. For example, gene expression levels of multiple genes can be measured for a patient (as by evaluating gene expression using an Affymetrix microarray chip) and
10 compared to a list of genes whose expression levels (high or low) are associated with a positive (or negative) outcome. If the gene expression profile of the patient is similar to that of the list of genes associated with outcome, then the patient can be assigned to a low (or high, as the case may be) risk category. The correlation between gene expression profiles and class distinction can be determined using a variety of
15 methods. Methods of defining classes and classifying samples are described, for example, in Golub et al, U.S. Patent Application Publication No. 2003/0017481 published January 23, 2003, and Golub et al., U.S. Patent Application Publication No. 2003/0134300, published July 17, 2003. The information provided by the present invention, alone or in conjunction with other test results, aids in sample classification
20 and diagnosis of disease.

Computational analysis using the gene lists and other data, such as measures of statistical significance, as described herein is readily performed on a computer. The invention should therefore be understood to encompass machine readable media comprising any of the data, including gene lists, described herein. The invention
25 further includes an apparatus that includes a computer comprising such data and an output device such as a monitor or printer for evaluating the results of computational analysis performed using such data.

In another aspect, the invention provides genes and gene expression profiles that are correlated with cytogenetics. This allows discrimination among the various
30 karyotypes, such as MLL translocations or numerical imbalances such as hyperdiploidy or hypodiploidy, which are useful in risk assessment and outcome prediction.

In yet another aspect, the invention provides genes and gene expression profiles that are correlated with intrinsic disease biology and/or etiology. In other

words, gene expression profiles that are common or shared among individual leukemia cases in different patients can be used to define intrinsically related groups (often referred to as clusters) of acute leukemia that cannot be appreciated or diagnosed using standard means such as morphology, immunophenotype, or cytogenetics. Mathematical modeling of the very sharp peak in ALL incidence seen in children 2-3 years old (>80 cases per million) has suggested that ALL may arise from two primary events, the first of which occurs *in utero* and the second after birth (Linnet et al., Descriptive epidemiology of the leukemias, in Leukemias, 5th Edition. ES Henderson et al. (eds). WB Saunders, Philadelphia. 1990). Interestingly, the detection of certain ALL-associated genetic abnormalities in cord blood samples taken at birth from children who are ultimately affected by disease supports this hypothesis (Gale et al., Proc. Natl. Acad. Sci. U.S.A., 94:13950-13954, 1997; Ford et al., Proc. Natl. Acad. Sci. U.S.A., 95:4584-4588, 1998).

Our results for both infant leukemia and pediatric ALL suggest that this disease is composed of novel intrinsic biologic clusters defined by shared gene expression profiles, and that these intrinsic subsets cannot be defined or predicted by traditional labels currently used for risk classification or by the presence or absence of specific cytogenetic abnormalities. We have identified 9 novel groups for pediatric ALL and 3 novel groups for infant leukemia using unsupervised learning methods for class discovery, and have used supervised learning methods for class prediction and outcome correlations that have identified candidate genes associated with classification and outcome. The gene expression profiles in the infant leukemia clusters provide some clues to novel and independent etiologies.

Some genes in these clusters are metabolically related, suggesting that a metabolic pathway that is associated with cancer initiation or progression. Other genes in these metabolic pathways, like the genes described herein but upstream or downstream from them in the metabolic pathway, thus can also serve as therapeutic targets.

In yet another aspect, the invention provides genes and gene expression profiles that discriminate acute myeloid leukemia (AML) from acute lymphoblastic leukemia (ALL) in infant leukemias by measuring the expression levels of a gene product correlated with ALL or AML.

Another aspect of the invention provides genes and gene expression profiles that discriminate pre-B lineage ALL from T ALL in pediatric leukemias by measuring expression levels of a gene product correlated with pre-B lineage ALL or T ALL.

It should be appreciated that while the present invention is described primarily in terms of human disease, it is useful for diagnostic and prognostic applications in other mammals as well, particularly in veterinary applications such as those related to the treatment of acute leukemia in cats, dogs, cows, pigs, horses and rabbits.

Further, the invention provides methods for computational and statistical methods for identifying genes, lists of genes and gene expression profiles associated with outcome, karyotype, disease subtype and the like as described herein.

Measurement of gene expression levels

Gene expression levels are determined by measuring the amount or activity of a desired gene product (i.e., an RNA or a polypeptide encoded by the coding sequence of the gene) in a biological sample. Any biological sample can be analyzed. Preferably the biological sample is a bodily tissue or fluid, more preferably it is a bodily fluid such as blood, serum, plasma, urine, bone marrow, lymphatic fluid, and CNS or spinal fluid. Preferably, samples containing mononuclear blood cells and/or bone marrow fluids and tissues are used. In embodiments of the method of the invention practiced in cell culture (such as methods for screening compounds to identify therapeutic agents), the biological sample can be whole or lysed cells from the cell culture or the cell supernatant.

Gene expression levels can be assayed qualitatively or quantitatively. The level of a gene product is measured or estimated in a sample either directly (e.g., by determining or estimating absolute level of the gene product) or relatively (e.g., by comparing the observed expression level to a gene expression level of another samples or set of samples). Measurements of gene expression levels may, but need not, include a normalization process.

Typically, mRNA levels (or cDNA prepared from such mRNA) are assayed to determine gene expression levels. Methods to detect gene expression levels include Northern blot analysis (e.g., Harada et al., Cell 63:303-312 (1990)), S1 nuclease mapping (e.g., Fujita et al., Cell 49:357-367 (1987)), polymerase chain reaction (PCR), reverse transcription in combination with the polymerase chain reaction (RT-PCR) (e.g., Example III; see also Makino et al., Technique 2:295-301(1990)), and

reverse transcription in combination with the ligase chain reaction (RT-LCR).

Multiplexed methods that allow the measurement of expression levels for many genes simultaneously are preferred, particularly in embodiments involving methods based on gene expression profiles comprising multiple genes. In a preferred embodiment, gene expression is measured using an oligonucleotide microarray, such as a DNA microchip, as described in the examples below. DNA microchips contain oligonucleotide probes affixed to a solid substrate, and are useful for screening a large number of samples for gene expression.

Alternatively or in addition, polypeptide levels can be assayed.

Immunological techniques that involve antibody binding, such as enzyme linked immunosorbent assay (ELISA) and radioimmunoassay (RIA), are typically employed. Where activity assays are available, the activity of a polypeptide of interest can be assayed directly.

The observed expression levels for the gene(s) of interest are evaluated to determine whether they provide diagnostic or prognostic information for the leukemia being analyzed. The evaluation typically involves a comparison between observed gene expression levels and either a predetermined gene expression level or threshold value, or a gene expression level that characterizes a control sample. The control sample can be a sample obtained from a normal (i.e., non-leukemic patient) or it can be a sample obtained from a patient with a known leukemia. For example, if a cytogenic classification is desired, the biological sample can be interrogated for the expression level of a gene correlated with the cytogenic abnormality, then compared with the expression level of the same gene in a patient known to have the cytogenetic abnormality (or an average expression level for the gene that characterizes that population).

Treatment of infant leukemia and pediatric ALL

The genes identified herein that are associated with outcome and/or specific disease subtypes or karyotypes are likely to have a specific role in the disease condition, and hence represent novel therapeutic targets. Thus, another aspect of the invention involves treating infant leukemia and pediatric ALL patients by modulating the expression of one or more genes described herein.

In the case of OPAL1/G0, whose increased expression above threshold values is associated with a positive outcome, the treatment method of the invention involves

enhancing OPAL1/G0 expression. For a number of the gene products identified herein increased expression is correlated with positive outcomes in leukemia patients. Thus, the invention includes a method for treating leukemia, such as infant leukemia and/or pediatric ALL, that involves administering to a patient a therapeutic agent that
5 causes an increase in the amount or activity of OPAL1/G0 and/or other polypeptides of interest that have been identified herein to be positively correlated with outcome. Preferably the increase in amount or activity of the selected gene product is at least 10%, preferably 25%, most preferably 100% above the expression level observed in the patient prior to treatment.

10 The therapeutic agent can be a polypeptide having the biological activity of the polypeptide of interest (e.g., an OPAL1/G0 polypeptide) or a biologically active subunit or analog thereof. Alternatively, the therapeutic agent can be a ligand (e.g., a small non-peptide molecule, a peptide, a peptidomimetic compound, an antibody, or the like) that agonizes (i.e., increases) the activity of the polypeptide of interest. For
15 example, in the case of OPAL1/G0, which is postulated to be a membrane-bound protein that may function as a receptor or signaling molecule, the invention encompasses the use of a proline-rich ligand of the WW-binding protein 1 to agonize OPAL1/G0 activity.

Gene therapies can also be used to increase the amount of a polypeptide of
20 interest, such as OPAL1/G0 in a host cell of a patient. Polynucleotides operably encoding the polypeptide of interest can be delivered to a patient either as "naked DNA" or as part of an expression vector. The term vector includes, but is not limited to, plasmid vectors, cosmid vectors, artificial chromosome vectors, or, in some aspects of the invention, viral vectors. Examples of viral vectors include adenovirus,
25 herpes simplex virus (HSV), alphavirus, simian virus 40, picornavirus, vaccinia virus, retrovirus, lentivirus, and adeno-associated virus. Preferably the vector is a plasmid. In some aspects of the invention, a vector is capable of replication in the cell to which it is introduced; in other aspects the vector is not capable of replication. In some preferred aspects of the present invention, the vector is unable to mediate the
30 integration of the vector sequences into the genomic DNA of a cell. An example of a vector that can mediate the integration of the vector sequences into the genomic DNA of a cell is a retroviral vector, in which the integrase mediates integration of the retroviral vector sequences. A vector may also contain transposon sequences that facilitate integration of the coding region into the genomic DNA of a host cell.

Selection of a vector depends upon a variety of desired characteristics in the resulting construct, such as a selection marker, vector replication rate, and the like. An expression vector optionally includes expression control sequences operably linked to the coding sequence such that the coding region is expressed in the cell. The invention is not limited by the use of any particular promoter, and a wide variety is known. Promoters act as regulatory signals that bind RNA polymerase in a cell to initiate transcription of a downstream (3' direction) operably linked coding sequence. The promoter used in the invention can be a constitutive or an inducible promoter. It can be, but need not be, heterologous with respect to the cell to which it is introduced.

Another option for increasing the expression of a gene like OPAL1/G0 wherein higher expression levels are predictive for outcome is to reduce the amount of methylation of the gene. Demethylation agents, therefore, can be used to re-activate expression of OPAL/G0 in cases where methylation of the gene is responsible for reduced gene expression in the patient.

For other genes identified herein as being correlated without outcome in infant leukemia or pediatric ALL, high expression of the gene is associated with a negative outcome rather than a positive outcome. An example of this type of gene is PBK1. These genes (and their associated gene products) accordingly represent novel therapeutic targets, and the invention provides a therapeutic method for reducing the amount and/or activity of these polypeptides of interest in a leukemia patient. Preferably the amount or activity of the selected gene product is reduced to at least 90%, more preferably at least 75%, most preferably at least 25% of the gene expression level observed in the patient prior to treatment

A cell manufactures proteins by first transcribing the DNA of a gene for that protein to produce RNA (transcription). In eukaryotes, this transcript is an unprocessed RNA called precursor RNA that is subsequently processed (e.g. by the removal of introns, splicing, and the like) into messenger RNA (mRNA) and finally translated by ribosomes into the desired protein. This process may be interfered with or inhibited at any point, for example, during transcription, during RNA processing, or during translation. Reduced expression of the gene(s) leads to a decrease or reduction in the activity of the gene product.

The therapeutic method for inhibiting the activity of a gene whose expression is correlated with negative outcome involves the administration of a therapeutic agent to the patient. The therapeutic agent can be a nucleic acid, such as an antisense RNA

or DNA, or a catalytic nucleic acid such as a ribozyme, that reduces activity of the gene product of interest by directly binding to a portion of the gene encoding the enzyme (for example, at the coding region, at a regulatory element, or the like) or an RNA transcript of the gene (for example, a precursor RNA or mRNA, at the coding region or at 5' or 3' untranslated regions) (see, e.g., Golub et al., U.S. Patent Application Publication No. 2003/0134300, published July 17, 2003). Alternatively, the nucleic acid therapeutic agent can encode a transcript that binds to an endogenous RNA or DNA; or encode an inhibitor of the activity of the polypeptide of interest. It is sufficient that the introduction of the nucleic acid into the cell of the patient is or can be accompanied by a reduction in the amount and/or the activity of the polypeptide of interest. An RNA aptamer can also be used to inhibit gene expression. The therapeutic agent may also be protein inhibitor or antagonist, such as small non-peptide molecule such as a drug or a prodrug, a peptide, a peptidomimetic compound, an antibody, a protein or fusion protein, or the like that acts directly on the polypeptide of interest to reduce its activity.

The invention includes a pharmaceutical composition that includes an effective amount of a therapeutic agent as described herein as well as a pharmaceutically acceptable carrier. Therapeutic agents can be administered in any convenient manner including parenteral, subcutaneous, intravenous, intramuscular, intraperitoneal, intranasal, inhalation, transdermal, oral or buccal routes. The dosage administered will be dependent upon the nature of the agent; the age, health, and weight of the recipient; the kind of concurrent treatment, if any; frequency of treatment; and the effect desired. A therapeutic agent identified herein can be administered in combination with any other therapeutic agent(s) such as immunosuppressives, cytotoxic factors and/or cytokine to augment therapy, see Golub et al, Golub et al., U.S. Patent Application Publication No. 2003/0134300, published July 17, 2003, for examples of suitable pharmaceutical formulations and methods, suitable dosages, treatment combinations and representative delivery vehicles.

The effect of a treatment regimen on an acute leukemia patient can be assessed by evaluating, before, during and/or after the treatment, the expression level of one or more genes as described herein. Preferably, the expression level of gene(s) associated with outcome, such as OPAL1/G0, G1 and/or G2 are monitored over the course of the treatment period. Optionally gene expression profiles showing the expression levels of multiple selected genes associated with outcome can be produced at different times

during the course of treatment and compared to each other and/or to an expression profile correlated with outcome.

Screening for therapeutic agents

5 The invention further provides methods for screening to identify agents that modulate expression levels of the genes identified herein that are correlated with outcome, risk assessment or classification, cytogenetics or the like. Candidate compounds can be identified by screening chemical libraries according to methods well known to the art of drug discovery and development (see Golub et al., U.S. Patent Application Publication No. 2003/0134300, published July 17, 2003, for a detailed description of a wide variety of screening methods). The screening method of the invention is preferably carried out in cell culture, for example using leukemic cell lines that express known levels of the therapeutic target, such as OPAL1/G0. The cells are contacted with the candidate compound and changes in gene expression of one or more genes relative to a control culture are measured. Alternatively, gene expression levels before and after contact with the candidate compound can be measured. Changes in gene expression indicate that the compound may have therapeutic utility. Structural libraries can be surveyed computationally after identification of a lead drug to achieve rational drug design of even more effective compounds.

20 The invention further relates to compounds thus identified according to the screening methods of the invention. Such compounds can be used to treat infant leukemia and/or pediatric ALL, as appropriate, and can be formulated for therapeutic use as described above.

25

OPAL1 polynucleotide, polypeptide and antibody

 The invention includes novel nucleotide sequences found to be strongly associated with outcome in pediatric ALL, as well as the novel polypeptides they encode. These sequences, which we originally called "G0" but now have named OPAL1 for Outcome Predictor in Acute Leukemia, appear to be associated with alternatively spliced products of a large and complex gene. Alternate 5' exon usage likely causes the production of more than one distinct protein from the genomic sequence. We have now fully cloned both the genomic and cDNA sequences (SEQ

ID NO:16) of OPAL1. Expression levels of OPAL1/G0 that are high in relation to a predetermined threshold or a control sample are indicative of good prognosis.

Nucleotide sequences (SEQ ID NOs:1 and 3) encoding two alternatively spliced forms of the polypeptide gene product, OPAL1/G0, are shown in Fig. 2. The putative amino acid sequences (SEQ ID NOs:2 and 4) of the two forms of protein OPAL1/G0 are also shown in Fig. 2. Analysis of the protein sequence suggests that OPAL1/G0 may be a transmembrane protein with a short (53 amino acid) extracellular domain and an intracellular domain. Both the short extracellular and longer intracellular domains have proline-rich regions that are homologous to proteins that bind WW domains such as the WBP-1 Domain-Binding Protein 1 located at human chromosome 2p12 (MIM #60691; WBP1 in HUGO; UniGene Hs. 7709). Like SH3 domains in proteins, WW domains interact with proline-rich transcription factors and cytoplasmic signaling molecules (such as OPAL1/G0) to mediate protein-protein interactions regulating gene expression and cell signaling. The data suggest that this novel coding sequence encodes a signaling protein having a WW-binding domain and it likely plays an important role in regulation of these cellular processes.

The present invention also includes polypeptides with an amino acid sequence having at least about 80% amino acid identity, at least about 90% amino acid identity, or about 95% amino acid identity with SEQ ID NO:2 or 4. Amino acid identity is defined in the context of a comparison between an amino acid sequence and SEQ ID NO:2 or 4, and is determined by aligning the residues of the two amino acid sequences (i.e., a candidate amino acid sequence and the amino acid sequence of SEQ ID NO:2 or 4) to optimize the number of identical amino acids along the lengths of their sequences; gaps in either or both sequences are permitted in making the alignment in order to optimize the number of identical amino acids, although the amino acids in each sequence must nonetheless remain in their proper order. A candidate amino acid sequence is the amino acid sequence being compared to an amino acid sequence present in SEQ ID NO:2 or 4. A candidate amino acid sequence can be isolated from a natural source, or can be produced using recombinant techniques, or chemically or enzymatically synthesized. Preferably, two amino acid sequences are compared using the Blastp program of the BLAST 2 search algorithm, as described by Tatusova et al. (FEMS Microbiol. Lett., 174:247-250, 1999, and available on the world wide web at ncbi.nlm.nih.gov/gorf/bl2.html). Preferably, the default values for all BLAST 2 search parameters are used, including matrix =

BLOSUM62; open gap penalty = 11, extension gap penalty = 1, gap x dropoff = 50, expect = 10, wordsize = 3, and optionally, filter on. In the comparison of two amino acid sequences using the BLAST2 search algorithm, amino acid identity is referred to as "identities." A polypeptide of the present invention that has at least about 80%

5 identity with SEQ ID NO:2 or 4 also has the biological activity of OPAL1/G0.

The polypeptides of this aspect of the invention also include an active analog of SEQ ID NO:2 or 4. Active analogs of SEQ ID NO:2 or 4 include polypeptides having amino acid substitutions that do not eliminate the ability to perform the same biological function(s) as OPAL1/G0. Substitutes for an amino acid may be selected
10 from other members of the class to which the amino acid belongs. For example, nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, phenylalanine, tryptophan, and tyrosine. Polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, aspartate, and glutamate. The positively charged (basic) amino acids include arginine, lysine, and histidine. The negatively
15 charged (acidic) amino acids include aspartic acid and glutamic acid. Such substitutions are known to the art as conservative substitutions. Specific examples of conservative substitutions include Lys for Arg and *vice versa* to maintain a positive charge; Glu for Asp and *vice versa* to maintain a negative charge; Ser for Thr so that a free -OH is maintained; and Gln for Asn to maintain a free NH₂.

20 Active analogs, as that term is used herein, include modified polypeptides. Modifications of polypeptides of the invention include chemical and/or enzymatic derivatizations at one or more constituent amino acids, including side chain modifications, backbone modifications, and N- and C- terminal modifications including acetylation, hydroxylation, methylation, amidation, and the attachment of
25 carbohydrate or lipid moieties, cofactors, and the like.

The present invention further includes polynucleotides encoding the amino acid sequence of SEQ ID NO:2 or 4. An example of the class of nucleotide sequences encoding the polypeptide having SEQ ID NO:2 is SEQ ID NO:1; and an example of the class of nucleotide sequences encoding the polypeptide having SEQ ID NO:4 is
30 SEQ ID NO:3. The other nucleotide sequences encoding the polypeptides having SEQ ID NO:2 or 4 can be easily determined by taking advantage of the degeneracy of the three letter codons used to specify a particular amino acid. The degeneracy of the genetic code is well known to the art and is therefore considered to be part of this disclosure. The classes of nucleotide sequences that encode SEQ ID NO:2 and 4 are

large but finite, and the nucleotide sequence of each member of the classes can be readily determined by one skilled in the art by reference to the standard genetic code.

The present invention also includes polynucleotides with a nucleotide sequence having at least about 90% nucleotide identity, at least about 95% nucleotide identity, or about 98% nucleotide identity with SEQ ID NO:1 or 3. Nucleotide identity is defined in the context of a comparison between an nucleotide sequence and SEQ ID NO:1 or 3, and is determined by aligning the residues of the two nucleotide sequences (i.e., a candidate nucleotide sequence and the nucleotide sequence of SEQ ID NO:1 or 3) to optimize the number of identical nucleotides along the lengths of their sequences; gaps in either or both sequences are permitted in making the alignment in order to optimize the number of identical nucleotides, although the nucleotides in each sequence must nonetheless remain in their proper order. A candidate nucleotide sequence is the nucleotide sequence being compared to an nucleotide sequence present in SEQ ID NO:2 or 4. A candidate nucleotide sequence can be isolated from a natural source, or can be produced using recombinant techniques, or chemically or enzymatically synthesized. Percent identity is determined by aligning two polynucleotides to optimize the number of identical nucleotides along the lengths of their sequences; gaps in either or both sequences are permitted in making the alignment in order to optimize the number of shared nucleotides, although the nucleotides in each sequence must nonetheless remain in their proper order. For example, the two nucleotide sequences are readily compared using the Blastn program of the BLAST 2 search algorithm, as described by Tatusova et al. (*FEMS Microbiol. Lett.*, 174:247-250, 1999). Preferably, the default values for all BLAST 2 search parameters are used, including reward for match =1, penalty for mismatch = -2, open gap penalty = 5, extension gap penalty = 2, gap x_dropoff = 50, expect = 10, wordsize = 11, and filter on.

Examples of polynucleotides encoding a polypeptide of the present invention also include those having a complement that hybridizes to the nucleotide sequence SEQ ID NO:1 or 3 under defined conditions. The term "complement" refers to the ability of two single stranded polynucleotides to base pair with each other, where an adenine on one polynucleotide will base pair to a thymine on a second polynucleotide and a cytosine on one polynucleotide will base pair to a guanine on a second polynucleotide. Two polynucleotides are complementary to each other when a nucleotide sequence in one polynucleotide can base pair with a nucleotide sequence in

a second polynucleotide. For instance, 5'-ATGC and 5'-GCAT are complementary. As used herein, "hybridizes," "hybridizing," and "hybridization" means that a single stranded polynucleotide forms a noncovalent interaction with a complementary polynucleotide under certain conditions. Typically, one of the polynucleotides is
5 immobilized on a membrane. Hybridization is carried out under conditions of stringency that regulate the degree of similarity required for a detectable probe to bind its target nucleic acid sequence. Preferably, at least about 20 nucleotides of the complement hybridize with SEQ ID NO:1 or 3, more preferably at least about 50 nucleotides, most preferably at least about 100 nucleotides.

10 Also provided by the invention is an OPAL1/G0 antibody, or antigen-binding portion thereof, that binds the novel protein OPAL1/G0. OPAL1/G0 antibodies can be used to detect OPAL1/G0 protein; they are also useful therapeutically to modulate expression of the OPAL1/G0 gene. An antibody may be polyclonal or monoclonal. Methods for making polyclonal and monoclonal antibodies are well known to the art.
15 Monoclonal antibodies can be prepared, for example, using hybridoma techniques, recombinant, and phage display technologies, or a combination thereof. See Golub et al., U.S. Patent Application Publication No. 2003/0134300, published July 17, 2003, for a detailed description of the preparation and use of antibodies as diagnostics and therapeutics.

20 Preferably the antibody is a human or humanized antibody, especially if it is to be used for therapeutic purposes. A human antibody is an antibody having the amino acid sequence of a human immunoglobulin and include antibodies produced by human B cells, or isolated from human sera, human immunoglobulin libraries or from animals transgenic for one or more human immunoglobulins and that do not express
25 endogenous immunoglobulins, as described in U.S. Pat. No. 5,939,598 by Kucherlapati et al., for example. Transgenic animals (e.g., mice) that are capable, upon immunization, of producing a full repertoire of human antibodies in the absence of endogenous immunoglobulin production can be employed. For example, it has been described that the homozygous deletion of the antibody heavy chain joining
30 region (J(H)) gene in chimeric and germ-line mutant mice results in complete inhibition of endogenous antibody production. Transfer of the human germ-line immunoglobulin gene array in such germ-line mutant mice will result in the production of human antibodies upon antigen challenge (see, e.g., Jakobovits et al., Proc. Natl. Acad. Sci. U.S.A., 90:2551-2555 (1993); Jakobovits et al., Nature,

362:255-258 (1993); Bruggemann et al., Year in Immuno., 7:33 (1993)). Human antibodies can also be produced in phage display libraries (Hoogenboom et al., J. Mol. Biol., 227:381 (1991); Marks et al., J. Mol. Biol., 222:581 (1991)). The techniques of Cote et al. and Boerner et al. are also available for the preparation of human monoclonal antibodies (Cole et al., Monoclonal Antibodies and Cancer Therapy, Alan R. Liss, p. 77 (1985); Boerner et al., J. Immunol., 147(1):86-95 (1991)).

Antibodies generated in non-human species can be "humanized" for administration in humans in order to reduce their antigenicity. Humanized forms of non-human (e.g., murine) antibodies are chimeric immunoglobulins, immunoglobulin chains or fragments thereof (such as Fv, Fab, Fab', F(ab')₂, or other antigen-binding subsequences of antibodies) which contain minimal sequence derived from non-human immunoglobulin. Residues from a complementary determining region (CDR) of a human recipient antibody are replaced by residues from a CDR of a non-human species (donor antibody) such as mouse, rat or rabbit having the desired specificity. Optionally, Fv framework residues of the human immunoglobulin are replaced by corresponding non-human residues. See Jones et al., Nature, 321:522-525 (1986); Riechmann et al., Nature, 332:323-327 (1988); and Presta, Curr. Op. Struct. Biol., 2:593-596 (1992). Methods for humanizing non-human antibodies are well known in the art. See Jones et al., Nature, 321:522-525 (1986); Riechmann et al., Nature, 332:323-327 (1988); Verhoeyen et al., Science, 239:1534-1536 (1988); and (U.S. Pat. No. 4,816,567).

Laboratory applications

The present invention further includes a microchip for use in clinical settings for detecting gene expression levels of one or more genes described herein as being associated with outcome, risk classification, cytogenics or subtype in infant leukemia and pediatric ALL. In a preferred embodiment, the microchip contains DNA probes specific for the target gene(s). Also provided by the invention is a kit that includes means for measuring expression levels for the polypeptide product(s) of one or more such genes, preferably OPAL/G0, G1, G2, FYN binding protein, PBK1, or any of the genes listed in Table 42. In a preferred embodiment, the kit is an immunoreagent kit and contains one or more antibodies specific for the polypeptide(s) of interest.

EXAMPLES

The present invention is illustrated by the following examples. It is to be understood that the particular examples, materials, amounts, and procedures are to be interpreted broadly in accordance with the scope and spirit of the invention as set forth herein

EXAMPLE IA.

Laboratory Methods and Cohort Design

Leukemia Blast Purification, RNA Isolation, Amplification and Hybridization to Oligonucleotide Arrays

Laboratory techniques were developed to optimize sample handling and processing for high quality microarray studies for gene expression profiling in leukemia samples. Reproducible methods were developed for leukemia blast purification, RNA isolation, linear amplification, and hybridization to oligonucleotide arrays. Our optimized approach is a modification of a double amplification method originally developed by Ihor Lemischka and colleagues from Princeton University (Ivanova et al., Science 298(5593):601-604 (2002)).

Total RNA was isolated from leukemic blasts using Qiagen Rneasy. An average of 2×10^7 cells were used for total RNA extraction with the Qiagen RNeasy mini kit (Valencia, CA). The yield and integrity of the purified total RNA were assessed with the RiboGreen assay (Molecular Probes, Eugene, OR) and the RNA 6000 Nano Chip (Agilent Technologies, Palo Alto, CA), respectively.

Complementary RNA (cRNA) target was prepared from 2.5 μ g total RNA using two rounds of Reverse Transcription (RT) and In Vitro Transcription (IVT). Following denaturation for 5 minutes at 70°C, the total RNA was mixed with 100 pmol T7- (dT)₂₄ oligonucleotide primer (Genset Oligos, La Jolla, CA) and allowed to anneal at 42°C. The mRNA was reverse transcribed with 200 units Superscript II (Invitrogen, Grand Island, NY) for 1 hour at 42°C. After RT, 0.2 volume 5X second strand buffer, additional dNTP, 40 units DNA polymerase I, 10 units DNA ligase, 2 units RnaseH (Invitrogen) were added and second strand cDNA synthesis was performed for 2 hours at 16°C. After T4 DNA polymerase (10 units), the mix was

incubated an additional 10 minutes at 16°C. An equal volume of phenol:chloroform:isoamyl alcohol (25:24:1)(Sigma, St. Louis, MO) was used for enzyme removal. The aqueous phase was transferred to a microconcentrator (Microcon 50. Millipore, Bedford, MA) and washed/concentrated with 0.5 ml DEPC water twice the sample was concentrated to 10-20 ul. The cDNA was then transcribed with T7 RNA polymerase (Megascript, Ambion, Austin, TX) for 4 hr at 37°C. Following IVT, the sample was phenol:chloroform:isoamyl alcohol extracted, washed and concentrated to 10-20ul.

The first round product was used for a second round of amplification which utilized random hexamer and T7- (dT) 24 oligonucleotide primers, Superscript II, two RNase H additions, DNA polymerase I plus T4 DNA polymerase finally and a biotin-labeling high yield T7 RNA polymerase kit (Enzo Diagnostics, Farmingdale, NY). The biotin-labeled cRNA was purified on Qiagen RNeasy mini kit columns, eluted with 50ul of 45°C RNase-free water and quantified using the RiboGreen assay.

Following RNA isolation and cRNA amplification using two rounds of poly dT primer-anchored Reverse Transcription and T7 RNA polymerase transcription, RNA and cRNA quality was assessed by capillary electrophoresis on Agilent RNA Lab-Chips. After the quality check on Agilent Nano 900 Chips, 15ug cRNA were fragmented following the Affymetrix protocol (Affymetrix, Santa Clara, CA). The fragmented RNA was then hybridized for 20 hours at 45°C to HG_U95Av2 probes. The hybridized probe arrays were washed and stained with the EukGE_WS2 fluidics protocol (Affymetrix), including streptavidin phycoerythrin conjugate (SAPE, Molecular Probes, Eugene, OR) and an antibody amplification step (Anti-streptavidin, biotinylated, Vector Labs, Burlingame, CA). HG_U95Av2 chips were scanned at 488 nm, as recommended by Affymetrix. The expression value of each gene was calculated using Affymetrix Microarray Suite 5.0 software.

We routinely obtain 100-200 micrograms of amplified cRNA from 2.5 micrograms of leukemia cell-derived total RNA. Our detailed statistical analysis comparing various RNA inputs and single vs. double amplification methods have shown that this approach leads to an excellent representation of low as well as high abundance mRNAs and is highly reproducible. It has the added benefit of not losing the representation of low abundance genes frequently lost in methods that lack amplification or only perform single round amplifications. As only 15 micrograms of

cRNA are required per Affymetrix chip, we are able to store residual cRNA in virtually all cases; this highly valuable cRNA can be used again in the future as array platforms and methods of analysis improve. Samples were studied using oligonucleotide microarrays containing 12,625 probes (Affymetrix U95Av2 array platform).

Statistical design

We designed two retrospective cohorts of pediatric ALL patients registered to clinical trials previously coordinated by the Pediatric Oncology Group (POG): 1) a cohort 127 infant leukemias (the "infant" data set); and 2) a case control study of 254 pediatric B-precursor and T cell ALL cases (the "preB" dataset). These samples were obtained from patients with long term follow up who were registered to clinical trials completed by the Pediatric Oncology Group (POG). In the analysis of gene expression profiles for classification and particularly outcome prediction, it is essential to integrate gene expression data with laboratory parameters that impact the quality of the primary data, and to make sure that any derived cluster or gene list cannot be accounted for by variations in laboratory methodology. Thus we tracked and annotated our gene expression data set with all of the laboratory correlates shown below.

Laboratory Correlates

Vial Date = Sample Collection Date Value

Percent Leukemic Blasts in Sample = Integer

Sample Viability = Integer

RNA Method = Boolean

RNA Quality = Boolean

RNA Starting Amount = Amount Amplified (Floating Point)

Experimental Set = 16/Arrays per Set (Integer)

Amplification Date = Date Value (Linked to Reagent Lot)

aRNA Quality = Quality of Amplified RNA

Clinical, demographic, and outcome data are also essential for predictive profiling.

Clinical/Patient Sample Correlates

COG_NO = Patient Identifier (Integer)

Study_NO = Treatment Study (Integer)

AGE_DAYS = Age at Initial Registration (Integer)

RAC = Patient Race (Strings)

SX = Patient Sex (String)

5 WBC_BLD = Presenting Blood Count (Floating Point)

DUR_CR = Duration of Complete Remission (Days)

REMISS = (CCR=Continuous Complete Remission)

FAIL=Failed Therapy; String but representing a Boolean)

ACH-CR = Achieved Initial CR (String, but Boolean)

10 DI = DNA Index (Leukemia Cell DNA Amount, Floating)

KARYOTYP = Cytogenetic Abnormality

Blinded cohort studies were developed for the conduct of the array experiments. In this way, the individuals performing arrays were blinded to all clinical and outcome correlative variables.

15

For the retrospective "infant" study, 142 retrospective cases from two POG infant trials (9407 for infant ALL; 9421 for infant AML) were initially chosen for analysis. Infants as defined were <365 days in age and had overall extremely poor survival rates (<25%). Of the 142 cases, 127 were ultimately retained in the study; 15 cases were excluded from the final analysis due to poor quality total RNA, cRNA amplification, or hybridization. Of the final 127 cases analyzed, 79 were considered traditional ALL by morphology and immunophenotyping and 48 were considered AML. 59/127 of these cases had rearrangements of the MLL gene.

20

The 254 member retrospective pre-B and T cell ALL case control study (the "preB" study) was selected from a number of pediatric POG clinical trials. A cohort design was developed that could compare and contrast gene expression profiles in distinct cytogenetic subgroups of ALL patients who either did or did not achieve a long term remission (for example comparing children with t(4;11) who failed vs. those who achieved long term remission). Such a design allowed us to compare and contrast the gene expression profiles associated with different outcomes within each genetic group and to compare profiles between different cytogenetic abnormalities. The design was constructed to look at a number of small independent case-control studies within B precursor ALL and T cell ALL. For the B cell ALL group, the representative recurrent translocations included t(4;11), t(9;22), t(1;19), monosomy 7,

30

monosomy 21, Females, Males, African American, Hispanic, and AlinC15 arm A. Cases were selected from several completed POG trials, but the majority of cases came from the POG 9000 series, including 8602, 9406, 9005, and 9006 as long term follow up was available.

5 As standard cytogenetic analysis of the samples from patients registered to these older trials would not have usually detected the t(12;21), we performed RT-PCR studies on a large cohort of these cases to select ALL cases with t(12;21) who either failed (n=8) therapy or achieved long term remissions (n=22). Cases who "failed" had failed within 4 years while "controls" had achieved a complete continuous remission
10 of 4 or more years. A case-control study of induction failures (cases) vs. complete remissions (CRs; controls) was also included in this cohort design as was a T cell cohort.

It is very important to recognize that the study was designed for efficiency, and maximum overlap, without adversely affecting the random sampling assumptions
15 for the individual case-control studies. To design this cohort, the set of all patients (irrespective of study) who had inventory in the UNM POG/COG Tissue Repository and who had failed within 4 years of diagnosis (cases) were considered. Each such case was assigned a random number from zero to one. Cases were then sorted by this random number. The same process was applied to the totality of potential controls.

20 For each case-control study, we then took the first N patients (requested in design) or all patients (whichever was smaller), meeting the entry requirements for the particular study. By maximizing the overlap in this fashion, a savings of over 20% compared to a design that required mutually exclusive entries was achieved. Yet for any given case-control study, the patients represent pure random samples of cases and controls.

25 (For example if the first patient in the sort of the failure group were an African-American female with a t(1;19) translocation, she would participate in at least three case control studies). As for the infant leukemia cases, gene expression arrays were completed using 2.5 micrograms of RNA per case (all samples had >90% blasts) with double linear amplification. All amplified RNAs were hybridized to Affymetrix

30 U95A.v2 chips.

EXAMPLE IB.

Computational Methods

5 The present invention makes use of a suite of high-end analytic tools for the analysis of gene expression data. Many of these represent novel implementations or significant extensions of advanced techniques from statistical and machine learning theory, or new data mining approaches for dealing with high-dimensional and sparse datasets. The approaches can be categorized into two major groups: knowledge discovery environments, and supervised classification methodologies.

10

Clustering, Visualization, and Text-Mining

1. *VxInsight*

VxInsight is a data mining tool (Davidson et al., J. Intellig. Inform. Sys. 11:259-285, 1998; Davidson et al., *IEEE Information Visualization 2001*, 23-30, 2001) originally developed to cluster and organize bibliographic databases, which has been extended and customized for the clustering and visualization of genomic data. It presents an intuitive way to cluster and view gene expression data collected from microarray experiments (Kim et al., *Science* 293:2087-92, 2001). It can be applied equally to the clustering of genes (*e.g.*, in a time-series experiment) or to discover novel biologic clusters within a cohort of leukemia patient samples. Similar genes or patients are clustered together spatially and represented with a 3D terrain map, where the large mountains represent large clusters of similar genes/samples and smaller hills represent clusters with fewer genes/samples. The terrain metaphor is extremely intuitive, and allows the user to memorize the "landscape," facilitating navigation through large datasets.

VxInsight's clustering engine, or ordination program, is based on a force-directed graph placement algorithm that utilizes all of the similarities between objects in the dataset. When applied to gene clustering, for example, the algorithm assigns genes into clusters such that the sum of two opposing forces is minimized. One of these forces is repulsive and pushes pairs of genes away from each other as a function of the density of genes in the local area. The other force pulls pairs of similar genes together based on their degree of similarity. The clustering algorithm terminates when these forces are in equilibrium. User-selected parameters determine the

fineness of the clustering, and there is a tradeoff with respect to confidence in the reliability of the cluster *versus* further refinement into sub-clusters that may suggest biologically important hypotheses.

VxInsight was employed to identify clusters of infant leukemia patients with similar gene expression patterns, and to identify which genes strongly contributed to the separations. A suite of statistical analysis tools was developed for post-processing information gleaned from the *VxInsight* discovery process. Visual and clustering analyses generated gene lists, which when combined with public databases and research experience, suggest possible biological significance for those clusters. The array expression data were clustered by rows (similar genes clustered together), and by columns (patients with similar gene expression clustered together). In both cases Pearson's R was used to estimate the similarities. Analysis of variance (ANOVA) was used to determine which genes had the strongest differences between pairs of patient clusters. These gene lists were sorted into decreasing order based on the resulting *F*-scores, and were presented in an HTML format with links to the associated OMIM pages (Online Mendelian Inheritance in Man database, available on the world wide web through the National Center for Biotechnology Information), which were manually examined to hypothesize biological differences between the clusters. Gene list stability was investigated using statistical bootstraps (Efron, Ann. Statist. 7:1-26, 1979; Hjorth et al., *Computer Intensive Statistical Methods, Validation Model Selection and Bootstrap*. Chapman & Hall, London, 1994). For each pair of clusters 100 random bootstrap cases were constructed via resampling with replacement from the observed expressions (Fig. 3). Next, the resulting ordered lists of genes were determined, using the same ANOVA method as before. The average order in the set of bootstrapped gene lists was computed for all genes, and reported as an indication of rank order stability (the percentile from the bootstraps estimates a *p*-value for observing a gene at or above the list order observed using the original experimental values).

2. Principal Component Analysis

Principal component analysis (PCA) is a well-known and convenient method for performing unsupervised clustering of high-dimensional data. Closely related to the Singular Value Decomposition (SVD), PCA is an unsupervised data analysis technique whereby the most variance is captured in the least number of coordinates.

It can serve to reduce the dimensionality of the data while also providing significant noise reduction. It is a standard technique in data analysis and has been widely applied to microarray data. Recently (Raychaudhuri et al., Pac. Symp. Biocomput., 5:455–466, 2002) PCA was used to analyze cell cycles in yeast (Chu et al., Science, 282:699–705, 1998; Spellman et al., Mol. Biol. Cell, 9:3273–97, 1998); PCA has also been applied to clustering (Hastie et al., Genome Biology 1:research0003, 2000; Holter et al., Proc. Natl. Acad. Sci., 97:8409–14, 2000); other applications of PCA to microarray data have been suggested (Wall et al., Bioinformatics 17, 566–568, 2001).

PCA works by providing a statistically significant projection of a dataset onto an orthonormal basis. This basis is computed so that a variety of quantities are optimized. In particular we have (Kirby, *Geometric Data Analysis*. John Wiley & Sons, New York, 2001):

- maximization of the statistical variance,
- minimization of mean square truncation error,
- maximization of the mean squared projection,
- minimization of entropy.

Furthermore, the PCA basis optimizes these quantities by dimension. In other words, the first PCA basis vector provides the best one-dimensional projection of the data subject to the above conditions, the first and second PCA basis vectors provide the best two-dimensional projection, et cetera. The PCA basis is typically computed by solving an eigenvalue problem closely related to the SVD (Kirby, *Geometric Data Analysis*. John Wiley & Sons, New York, 2001; Trefethen et al., *Numerical Linear Algebra*. SIAM, Philadelphia, 1997). Consequently, the PCA basis vectors are often called eigenvectors; in the context of microarray data they are occasionally called eigen-genes, eigen-arrays, or eigen-patients. PCA is typically illustrated by finding the major and minor axes in a cloud of data filling an ellipse. The first eigenvector corresponds to the major axis of the ellipse while the second eigenvector corresponds to the minor axis. PCA is used to analyze the principal sources of error in microarray experiments, and to perform variance analysis of VxInsight-derived clusters.

1. Bayesian Networks

5 The Bayesian network modeling and learning paradigm (Pearl, *Probabilistic Reasoning for Intelligent Systems*. Morgan Kaufmann, San Francisco, 1988; Heckerman et al., *Machine Learning* 20:197-243, 1995) has been studied extensively in the statistical machine learning literature. A Bayesian net is a graph-based model for representing probabilistic relationships between random variables. The random variables, which may, for example, represent gene expression levels, are modeled as graph nodes; probabilistic relationships are captured by directed edges between the nodes and conditional probability distributions associated with the nodes. In the context of genomic analysis, this framework is particularly attractive because it allows hypotheses of actor interactions (e.g., gene-gene, gene-protein, gene-polymorphism) to be generated and evaluated in a mathematically sound manner against existing evidence. Network reconstruction, pathway identification, diagnosis, and outcome prediction are among the many challenges of current interest that Bayesian networks can address. Introduction of new network nodes (random variables) can model effects of previously hidden state variables, conditioning prediction on such factors as subject characteristics, disease subtype, polymorphic information, and treatment variables.

20 A Bayesian net asserts that each node (representing a gene or an outcome) is statistically independent of all its non-descendants, once the values of its parents (immediate ancestors) in the graph are known. Even with the focus on restricted subnetworks, the learning problem is enormously difficult, due to the large number of genes, the fact that the expression values of the genes are continuous, and the fact that expression data generally is rather noisy. Our approach to Bayesian network learning employs an initial gene selection algorithm to produce 20-30 genes, with a binary binning of each selected gene's expression value. The set of selected genes then is searched exhaustively for parent sets of size 5 or less, with the induced candidate networks being evaluated by the BD scoring metric (Heckerman et al., *Machine Learning* 20:197-243, 1995). This metric, along with our variance factor, is used to blend the predictions made by the 500 best scoring networks. Each of these 500 Bayesian networks can be viewed as a competing hypothesis for explaining the current evidence (i.e., training data and prior knowledge) for the

corresponding classification task, and the gene interactions each suggests are potentially of independent interest as well.

Bayesian analysis allows the combining of disparate evidence in a principled way. Abstractly, the analysis synthesizes known or believed prior domain information with bodies of possibly diverse observational and experimental data (e.g., microarrays giving gene expression levels, polymorphism information, clinical data) to produce probabilistic hypotheses of interaction and prediction. Prior elicitation and representation quantifies the strength of beliefs in domain information, allowing this knowledge and observational and experimental data to be handled in uniform manner. Strong priors are akin to plentiful and reliable data; weaker priors are akin to sparse, noisy data. Similarly, observational and experimental data can be qualified by its reliability, accuracy, and variability, taking into account the different sources that produced the data and inherent differences in the natures of the data. Of course, observational and experimental data will eventually dominate the analysis if it is of sufficient size and quality.

In the context of outcome and disease subtype prediction, we applied a highly customized and extended Bayesian net methodology to high-dimensional sparse data sets with feature interaction characteristics such as those found in the genomics application. These customizations included the parent-set model for Bayesian net classifiers, the blending of competing parent sets into a single classifier, the pre-filtering of genes for information content, Helman-Veroff normalization to pre-process the data, methods for discretizing continuous data, the inclusion of a variance term in the BD metric, and the setting of priors. Our normalization algorithm is designed to address inter-sample differences in gene expression levels obtained from the microarray experiments. It proceeds by scaling each sample's expression levels by a factor derived from the aggregate expression level of that sample. In this way, after scaling, all samples have the same aggregate expression level.

A set of training data, labeled with outcome or disease subtype, was used to generate and evaluate hypotheses against the training data. A cross validation methodology was employed to learn parameter settings appropriate for the domain. Surviving hypotheses were blended in the Bayesian framework, yielding conditional outcome distributions. Hypotheses so learned are validated against an out-of-sample test set in order to assess generalization accuracy. This approach was

successfully used to identify OPAL1/G0 as strong predictors of outcome in pediatric ALL as described in Example II.

2. Support Vector Machines.

Support vector machines (SVMs) are powerful tools for data classification (Cristianini et al., *An Introduction to Support Vector Machines and Other Kernel-Based Learning Methods*. Cambridge University Press, Cambridge, 2000; Vapnik, *Statistical Learning Theory*, John Wiley & Sons, New York, 1999). The original development of the SVM was motivated, in the simple case of two linearly separable classes, by the desire to choose an optimal linear classifier out of an infinite number of potential linear classifiers that could separate the data. This optimal classifier corresponds not only to a hyperplane that separates the classes but also to a hyperplane that attempts to be as far away as possible from all data points. If one imagines inserting the widest possible corridor between data points (with data points belonging to one class on one side of the corridor and data points belonging to the other class on the other side), then the optimal hyperplane would correspond to the imaginary line/plane/hyperplane running through the middle of this corridor.

The SVM has a number of characteristics that make it particularly appealing within the context of gene selection and the classification of gene expression data, namely: SVMs represent a multivariate classification algorithm that takes into account each gene simultaneously in a weighted fashion during training, and they scale quadratically with the number of training samples, N , rather than the number of features/genes, d . In order to be computationally feasible, other classification methods first have to reduce the number of dimensions (features/genes), and then classify the data in the reduced space. A univariate feature selection process or filter ranks genes according to how well each gene individually classifies the data. The overall classification is then heavily dependent upon how successful the univariate feature selection process is in pruning genes that have little class-distinction information content. In contrast, the SVM provides an effective mechanism for both classification and feature selection via the Recursive Feature Elimination algorithm (Guyon et al., *Machine Learning* 46, 389-422, 2002). This is a great advantage in gene expression problems where d is much greater than N , because the number of features does not have to be reduced *a priori*.

Recursive Feature Elimination (RFE) is an SVM-based iterative procedure that generates a nested sequence of gene subsets whereby the subset obtained at iteration $k+1$ is contained in the subset obtained at iteration k . The genes that are kept per iteration correspond to genes that have the largest weight magnitudes—the rationale being that genes with large weight magnitudes carry more information with respect to class discrimination than those genes with small weight magnitudes. We have implemented a version of SVM-RFE and obtained excellent results—comparable to Bayesian nets—for a range of infant leukemia classification tasks with blinded test sets.

3. Discriminant Analysis

Discriminant analysis is a widely used statistical analysis tool that can be applied to classification problems where a training set of samples, depending a set of p feature variables, is available (Duda et al., *Pattern Classification (Second Edition)*. Wiley, New York, 2001). Each sample is regarded as a point in p -dimensional space \mathbb{R}^p , and for a g -way classification problem, the training process yields a discriminant rule that partitions \mathbb{R}^p into g disjoint regions, R_1, R_2, \dots, R_g . New samples with unknown class labels can then be classified based on the region R_i to which the corresponding sample vector belongs. In many cases, determining the partitioning is equivalent to finding several linear or non-linear functions of the feature variables such that the value of the function differs significantly between different classes. This function is the so-called discriminant function. Discriminant rules fall into two categories: *parametric* and *nonparametric*. Parametric methods such as the maximum likelihood rule—including the special cases of linear discriminant analysis (LDA) and quadratic discriminant analysis (QDA) (Mardia et al., *Multivariate Analysis*. Academic Press, Inc., San Diego, 1979; Dudoit et al., J. Am. Stat. Ass'n. 97(457):77-87, 2002)—assume that there is an underlying probability distribution associated with each of the classes, and the training samples are used to estimate the distribution parameters. Non-parametric methods such as Fisher's linear discriminant and the k -nearest neighbor method (Duda et al., *Pattern Classification (Second Edition)*. Wiley, New York, 2001) do not utilize parameter estimation of an underlying distribution in order to perform classifications based on a training set.

In applying discriminant analysis techniques to the gene expression classification problem, both categories of methods have been utilized, specifically LDA (binary classification) and Fisher's linear discriminant (multi-class problems). For the statistically designed infant leukemia dataset, LDA was applied successfully to the AML/ALL and t(4;11)/NOT class distinctions. Fisher's linear discriminant analysis was further used to identify three well-separated classes that clustered within the seven nominal MLL subclasses for which karyotype labels were available.

For both classes of methods, a major issue is the question of feature selection, either as an independent step prior to classification, or as part of the classifier training step. In addition to a simple ranking based on *t*-test score as used by other researchers (Dudoit et al., J. Am. Stat. Ass'n. 97(457):77-87, 2002), the use of stepwise discriminant analysis for determining optimal sets of distinguishing genes has been investigated. One challenge in the stepwise approach is the rapid increase of computational burden with the number of genes included in the initial set; the method is therefore being implemented on large-scale parallel computers. An alternative gene selection approach that is presently being explored is stepwise logistic regression (McCulloch et al., *Generalized, Linear, and Mixed Models* Wiley, New York, 2001; SAS Online Documentation for SAS System, Release 8.02, SAS Institute, Inc. 2001). Logistic regression is known to be well suited to binary classification problems involving mixed categorical and continuous data or to cases where the data are not normally distributed within the respective classes.

Various extensions of these techniques are expected to enable the incorporation of both categorical and continuous data in our classifiers. This enables the inclusion of known, discrete clinical labels (age, sex, genotype, white blood count, etc.) in conjunction with microarray expression vectors, in order to perform more accurate classifications, particularly for outcome prediction. In addition to logistic regression as mentioned previously, one approach is to first quantify the categorical data (Hayashi, Ann. Inst. Statist.Math. 3:69-98, 1952), and then apply standard non-parameteric statistical classification techniques in the usual manner.

4. Fuzzy Inference

Traditional classification methods are based on the theory of crisp sets, where an element is either a member of a particular set or not. However many objects encountered in the real world do not fall into precisely defined membership criteria.

Fuzzy inference (also known as fuzzy logic) and adaptive neuro-fuzzy models are powerful learning methods for pattern recognition. Although researchers have previously investigated the use of fuzzy logic methods for reconstructing triplet relationships (activator/repressor/target) in gene regulatory networks (Woolf et al.,
5 Physiol. Genomics 3:9-15, 2000), these techniques have not been previously applied to the genomic classification problem. A significant advantage of fuzzy models is their ability to deal with problems where set membership is not binary (yes/no); rather, an element can reside in more than one set to varying degrees. For the
10 classification problem, this results in a model that, like probabilistic methods such as Bayesian nets, can accommodate data sources that are incomplete, noisy, and may ultimately include non-numeric text-based expert knowledge derived from clinical data; polymorphisms or other forms of genomic data; or proteomic data that must be incorporated into the overall model in order to achieve a more accurate
15 classification system in clinical contexts such as outcome prediction.

5. Genetic algorithms

Fuzzy logic and other classification methods require the use of a gene selection method in order to reduce the size of the feature space to a numerically tractable size, and identify optimal sets of class-distinguishing genes for further
20 analysis. We are exploring the use of genetic algorithms (GAs) for determining optimal feature sets during the training phase of a classification problem.

A GA is a simulation method that makes it possible to robustly search a very large space of possible solutions to an optimization problem, and find candidate solutions that are near optimal. Unlike traditional analytic approaches, GAs avoid
25 "local minimum" traps, a classic problem arising in high-dimensional search spaces. Optimal feature selection for gene expression data where the sample size N is much smaller than the number of features d (for the Affymetrix leukemia data analyzed, $d \approx 12,000$ and $N \approx 100-200$) is a classic problem of this type. A genetic algorithm code has been developed by us to perform feature selection for the K-nearest
30 neighbors classification method using the recently proposed GA/KNN approach (Li et al., Bioinformatics 17:1131-42, 2001); this method, which is compute-intensive, has been implemented on the parallel supercomputers. The approach has been applied recently to the statistically designed infant leukemia dataset, to evaluate

biologic clusters discovered using unsupervised learning (VxInsight). The GA/KNN method was able to predict the hypothesized cluster labels (A,B,C) in one-vs.-all classification experiments.

5

EXAMPLE II.

Identification of a Gene Strongly Predictive of Outcome in Pediatric Acute Lymphoblastic Leukemia (ALL): OPAL1

Summary

10 To identify genes strongly predictive of outcome in pediatric ALL, we analyzed the retrospective case control study of 254 pediatric ALL samples described in Example IA. We divided the retrospective POG ALL case control cohort (n=254) into training (2/3 of cases, the "preB training set") and test (1/3 of cases, the "preB test set") sets, applied a Bayesian network approach, and performed statistical analyses. A
15 particularly gene predictive of outcome in pediatric ALL was identified, corresponding to Affymetrix probe set 38652_at ("G0": Hs. 10346; NM_Hypothetical Protein FLJ20154; partial sequences reported in GenBank Accession Number NM_017787; NM_017690; XM_053688; NP_060257). Two other genes, Affymetrix probe set 34610_at ("G1": GNB2L1: G protein β 2, related sequence 1; GenBank
20 Accession Number NM_006098;); and Affymetrix probe set 35659_at ("G2": IL-10 Receptor alpha; GenBank Accession Number U00672), were identified as associated with outcome in conjunction with OPAL1/G0, but were substantially less significant. OPAL1/G0, which we have named OPAL1 for outcome predictor in acute leukemia, was a heretofore unknown human expressed sequence tag (EST), and had not been
25 fully cloned until now. G1 (G protein β 2, related sequence 1) encodes a novel RACK (receptor of activated protein kinase C) protein and is involved in signal transduction (Wang et al., Mol Biol Rep. 2003 Mar;30(1):53-60) and G2 is the well-known IL-10 receptor alpha.

Importantly, we found that OPAL1/G0 was highly predictive of outcome
30 (p=.0014) in a completely different set of ALL cases assessed by gene expression profiling by another laboratory (the St. Jude set of ALL cases previously published by Yeoh et al. (Cancer Cell 1; 133-143, 2002)). We also observed a trend between high OPAL1/G0 and improved outcome in our retrospective cohort of infant ALL cases.

We have fully cloned the human homologue of OPAL1/G0 and characterized its genomic structure. OPAL1/G0 is highly conserved among eukaryotes, maps to human chromosome 10q24, and appears to be a novel transmembrane signaling protein with a short membrane insertion sequence and a potential transmembrane domain. This protein may be a protein inserted into the extracellular membrane (and function like a signaling receptor) or within an intracellular domain. We have also developed specific automated quantitative real time RT-PCR assays to precisely monitor the expression of OPAL1/G0 and other genes that we have found to be associated with outcome in ALL.

Bayesian networks

We used Bayesian networks, a supervised learning algorithm as described in Example IB, to identify one or more genes that could be used to predict outcome as well as therapeutic resistance and treatment failure. To identify genes strongly predictive of outcome in pediatric ALL, we divided the retrospective POG ALL case control cohort (n=254) described above into training (2/3 of cases) and test (1/3 of cases) sets. Computational scientists were blinded to all clinical and biologic co-variables during training, except those necessary for the computational tasks. A large number of computational experiments were performed, in order to properly sample the space of Bayesian nets satisfying the constraints of the problem. In the context of high-dimensional gene expression data, the inclusion of more nets than is typical in the literature appears to yield better results. Our initial results using Bayesian nets showed classification rates in excess of 90-95%.

Identification of genes associated with outcome

A particularly strong set of genes predictive of outcome was identified by applying a Bayesian network analysis to the preB training set. The three genes in the strongest predictive tree identified by Bayesian networks are provided in Table 2.

Table 2: Genes Strongly Predictive of Outcome in Pediatric ALL

Gene Identifier: Bayesian Network	Affymetrix Oligo Sequence	Gene/Protein Name	Previously Known Function / Comment
G0	38652_at	Hs. 10346; NM_Hypothetical Protein FLJ20154	Unknown human EST, not previously fully cloned.
G1	34610_at	GNB2L1: G protein β 2, related sequence 1	Signal Transduction; Activator of Protein Kinase C
G2	35659_at	IL-10 Receptor alpha	IL-10 Receptor alpha

Fig.4 shows a graphic representation of statistics that were extracted from the Bayesian net (Bayesian tree) that show association with outcome in ALL. The circles represent the key genes; the lighter arrows pointing toward the left denote low expression levels while the darker arrows pointing toward the right denote high expression of each gene. The percentage of patients achieving remission (R) or therapeutic failure (F) is shown for high or low expression of each gene, along with the number of patients in each group in parentheses.

Our analysis showed that pediatric ALL patients whose leukemic cells contain relatively high levels of expression of OPAL1/G0 have an extremely good outcome while low levels of expression of OPAL1/G0 is associated with treatment failure. At the top of the Bayesian network, OPAL1/G0 conferred the strongest predictive power; by assessing the level of OPAL1/G0 expression alone, ALL cases could be split into those with good outcomes (OPAL1/G0 high: 87% long term remissions) versus those with poor outcomes (OPAL1/G0 low: 32% long term remissions, 68% treatment failure). Detailed statistical analyses of the significance of OPAL1/G0 expression in the retrospective cohort revealed that low OPAL1/G0 expression was associated with induction failure ($p=.0036$) while high OPAL1/G0 expression was associated with

long term event free survival ($p=.02$), particularly in males ($p=.0004$). Higher levels of OPAL1/G0 expression were also associated with certain cytogenetic abnormalities (such as $t(12;21)$) and normal cytogenetics. Although the number of cases were limited in our initial retrospective cohort, low levels of OPAL1/G0 appeared to define those patients with low risk ALL who failed to achieve long term remission, suggesting that OPAL1/G0 may be useful in prospectively identifying children who would otherwise be classified as having low or standard risk disease, but who would benefit from further intensification.

The pre-B test set (containing the remaining 87 members of the pre-B cohort) was also analyzed. Unexpectedly, OPAL1/G0 when evaluated on the pre B test set showed a far less significant correlation with outcome. This is the only one of the four data sets (infant, pre-B training set, pre-B test set, and the Downing data set, below) in which no correlation was observed. One possible explanation is that, despite the fact that the preB data set was split into training and test sets by what should have been a random process, in retrospect, the composition of the test set differed very significantly from the training set. For example, the test set contains a disproportionately high fraction of studies involving high risk patients with poorer prognosis cytogenetic abnormalities which lack OPAL1/G0 expression; these children were also treated on highly different treatment regimens than the patients in the training set. Thus, there may not have been enough leukemia cases that expressed higher OPAL1/G0 levels (there were only sixteen patients with a high OPAL1/G0 expression value in the test set) for us to reach statistical significance. Finally, the p-value observed for the preB training set was so strong, as was the validation p-value for OPAL1/G0 outcome prediction in the independent data sets, that it would be virtually impossible that the observed correlation between OPAL1/G0 and outcome is an artifact.

In addition, PCR experiments recently completed in accordance with the methods outlined in Example III support the importance of OPAL1/G0 as a predictor of outcome. Although a large fraction (30%) of the 253 pre B cases could not be assessed by PCR due to sample availability, including 8 of the 36 cases from the pre B training set in which OPAL1/G0 was highly expressed, an initial analysis of the results on the 174 cases which could be assessed supports a clear statistical correlation between OPAL1/G0 and outcome (a p-value of about 0.005 on the PCR data alone, when the OPAL1/G0-high threshold is considered fixed). It should be noted that

these PCR samples cut across the pre B training and test sets, and that the PCR results do not seem to reflect the same dichotomy in training and test set correlation as was seen in the microarray data. Furthermore, the RNA target for the PCR assays (directly amplified cDNA) and the Affymetrix array experiments (linearly amplified twice cDNA) are quite different and it is satisfying that a moderately strong correlation ($r = 0.62$) was observed between these two quite distinct methodologies to quantitate gene expression. Additionally, in a random re-sampling (bootstrap) procedure reported in herein, OPAL1/G0 does exhibit consistent significance.

As noted above, we evaluated expression levels of OPAL1/G0 in three entirely different and disjoint data sets. Two of the data sets, described above, were derived from retrospective cohorts of pediatric ALL patients registered to clinical trials previously coordinated by the Pediatric Oncology Group (POG): the statistically designed cohort of 127 infant leukemias (the "infant" data set); and the statistically designed case control study of 254 pediatric B-precursor and T cell ALL cases (the "pre-B" data set), specifically the 167 member "pre-B" training set. The third data set evaluated was a publicly available set of ALL cases previously published by Yeoh et al. (the "Downing" or "St. Jude" data set) (Cancer Cell 1; 133-143, 2002).

The following breakdown was conditioned on OPAL1/G0 expression level at its optimal threshold value, which in all data sets examined fell near the top quarter (22-25%) of the expression values. Low OPAL1/G0 expression was defined as having normalized OPAL1/G0 expression below this value, while high OPAL1/G0 expression was defined as having normalized OPAL1/G0 expression equal to or greater than this value.

Of the 167 members of the pre-B training set, 73 (44%) were classified as CCR (continuous complete remission) while 94 (56%) were classified as FAIL. Relative to the optimized threshold value, OPAL1/G0 expression was determined to be low in 131 samples and high in 36 samples. The following statistics were observed.

Low OPAL1/G0 expression (131 samples):

CCR: 42 32%

FAIL: 89 68%

High OPAL1/G0 expression (36 samples):

CCR: 31 86%

FAIL: 5 14%

5 The following p-values were observed for gene uncorrelated with outcome possessing any threshold point yielding our observations or better:

By Chi-squared: $p\text{-value} \approx 1.2 * 10^{-7}$ (approximately 1 in ten million)

By TNoM: $p\text{-value} \approx 5.7 * 10^{-7}$ (approximately 1 in two million).

10

where TNoM refers Threshold Number of Misclassifications = the number of misclassifications made by using a single-gene classifier with an optimally chosen threshold for separating the classes.

15 The significance of these p-values must be assessed in light of the fact that 12,000+ genes can be so considered (individually) against the training data. Even with $1.25 * 10^4$ candidate genes, under the null hypothesis of no associations, the expected number of genes that possess a threshold yielding our observation (or better) is still extremely small:

20

By Chi-squared: $(1.2 * 10^{-7}) * (1.25 * 10^4) = 1.5 * 10^{-3}$

By TNoM: $(5.7 * 10^{-7}) * (1.25 * 10^4) = 7.5 * 10^{-3}$

25

Hence, one would expect to have to search approximately 667 independent data sets, each similar in composition to our pre-B training set (each consisting of $1.25 * 10^4$ candidate genes and 167 cases), in order to find even a single gene in one of these 667 data sets possessing a threshold yielding our observations or better as measured by Chi-squared, due to chance alone. (Using the p-value obtained from the TNoM statistic, we would expect to have to search 133 similar, independent data sets to find even a single gene possessing a threshold yielding a TNoM score at least as good as our observation.) These p-values are highly significant and support the conclusion that the observed statistical correlations are real, with high confidence.

30

Our analysis of the pre-B training set showed that pediatric ALL patients whose leukemic cells contain relatively high levels of expression of OPAL1/G0 have

an extremely good outcome while low levels of expression of OPAL1/G0 is associated with treatment failure. In the entire pediatric ALL cohort under analysis, 44% of the patients were in long term remission for 4 or more years, while 56% of the patients had failed therapy within 4 years. At the top of the Bayesian network,

5 OPAL1/G0 conferred the strongest predictive power; by assessing the level of OPAL1/G0 expression alone, ALL cases could be split into those with good outcomes (OPAL1/G0 high: 87% long term remission; 13% failures) versus those with poor outcomes (OPAL1/G0 low: 32% long term remissions, 68% treatment failure). Although the numbers are quite small as we continue down the Bayesian tree,

10 outcome predictions can be somewhat refined by analyzing the expression levels of these G1 and G2.

We also investigated OPAL1/G0 expression level statistics across biological classifications typically utilized as predictive of outcome. The following represents a breakdown of OPAL1/G0 expression statistics within various subpopulations of the

15 pre-B training set. The OPAL1/G0 threshold obtained by optimization in the original pre-B training set analysis (a value of 795) was used.

Normal Genotype (65 members)

20	Outcome statistics
	26 CCR 40%
	39 FAIL 60%
	Low OPAL1/G0 expression (51 samples)
25	13 CCR 25%
	38 FAIL 75%
	High OPAL1/G0 expression (14 samples)
	13 CCR 93%
30	1 FAIL 7%

t(12:21) (equivalent to TEL/AML1 in Downing data set, below) (24 members)

Outcome statistics

5 18 CCR 75%
 6 FAIL 25%

Low OPAL1/G0 expression (bottom 78%; 10 samples)

10 6 CCR 60%
 4 FAIL 40%

High OPAL1/G0 expression (top 22%; 14 samples)

15 12 CCR 86%
 2 FAIL 14%

Hyperdiploid (17 members)

Outcome statistics

20 9 CCR 53%
 8 FAIL 47%

Low OPAL1/G0 expression (13 samples)

25 5 CCR 38%
 8 FAIL 62%

High OPAL1/G0 expression (4 samples)

30 4 CCR 100%
 0 FAIL 0%

t(4:11) and t(1:19) combined (35 members)

Outcome statistics

13 CCR 37%
22 FAIL 63%

Low OPAL1/G0 expression (34 samples)

13 CCR 38%

21 FAIL 62%

5 High OPAL1/G0 expression (1 sample)

0 CCR 0%

1 FAIL 100%

t(9:22) and hypodiploid combined (12 members)

10

Outcome statistics

2 CCR 17%

10 FAIL 83%

15 Low OPAL1/G0 expression (12 samples)

2 CCR 17%

10 FAIL 83%

High OPAL1/G0 expression (0 samples)

20

0 CCR --

0 FAIL --

Low Age (<= 10 years) (109 members)

25

Outcome statistics

55 CCR 50%

54 FAIL 50%

Low OPAL1/G0 expression (80 samples)

30

30 CCR 38%

50 FAIL 62%

High OPAL1/G0 expression (29 samples)

25 CCR 86%

4 FAIL 14%

High Age (> 10 years) (58 members)

5 Outcome statistics

18 CCR 31%

40 FAIL 69%

Low OPAL1/G0 expression (51 samples)

10 12 CCR 24%

39 FAIL 76%

High OPAL1/G0 expression (7 samples)

6 CCR 86%

15 1 FAIL 14%

Low WBC (<= 50,000) (79 members)

Outcome statistics

20 39 CCR 49%

40 FAIL 51%

Low OPAL1/G0 expression (58 samples)

21 CCR 36%

25 37 FAIL 64%

High OPAL1/G0 expression (21 samples)

18 CCR 86%

3 FAIL 14%

30

High WBC (> 50,000) (88 members)

Outcome statistics

34 CCR 39%

54 FAIL 61%

Low OPAL1/G0 expression (73 samples)

21 CCR 29%

5 52 FAIL 71%

High OPAL1/G0 expression (15 samples)

13 CCR 87%

2 FAIL 13%

10

The data evidence a number of interesting interactions between OPAL1/G0 and various parameters used for risk classification (karyotype and NCI risk criteria). Age and WBC (White Blood Count), in particular, are routinely used in the current risk stratification standards (age > 10 years or WBC > 50,000 are high risk), yet
15 OPAL1/G0 appears to be the dominant predictor within both of these groups. Indeed, OPAL1/G0 appears to "trump" outcome prediction based on these biological classifications. In other words, regardless of biological classification, roughly the same OPAL1/G0 statistics are observed. For example, even though MLL translocation t(12:21) is generally associated with very good outcome, when
20 OPAL1/G0 is low, the t(12:21) outcome is not nearly as good as when OPAL1/G0 is high. This association is also present in the Downing data set (see below), according to our analysis, although it was not recognized by Yeoh et al.

In our retrospective cohort balanced for remission/failure, OPAL1/G0 was more frequently expressed at higher levels in ALL cases with normal karyotype
25 (14/65, 22%), t(12;21) (14/24, 58%) and hyperdiploidy (4/17, 24%) compared to cases with t(1;19) (2%) and t(9;22) (0%). 86% of ALL cases with t(12;21) and high OPAL1/G0 achieved long term remission; while t(12;21) with low OPAL1/G0 had only a 40% remission rate. Interestingly, 100% of hyperdiploid cases and 93% of normal karyotype cases with high OPAL1/G0 attained remission, in contrast to an
30 overall remission rate of 40% in each of these genetic groups.

Although our cases numbers were small and the cases highly selected, there appeared to be a correlation between low OPAL1/G0 and failure to achieve remission in children with low risk disease, suggesting that OPAL1/G0 may be useful in prospectively identifying children with low or standard risk disease who would

benefit from further intensification. Interestingly, in children in the standard NCI risk group (age <10; WBC < 50,000) and an overall remission rate of 50% in this case control study, children with high OPAL1/G0 had an 86% long term remission rate. Even children with NCI high risk criteria (age > 10, WBC > 50,000) and an overall remission rate of 31% in this selected cohort, children with high OPAL1/G0 had an 87% remission rate. Finally, OPAL1/G0 was also highly predictive of outcome in T ALL (p=.02), as well as B precursor ALL.

Our statistical analyses of the significance of OPAL1/G0 expression in the retrospective cohort revealed that low OPAL1/G0 expression was associated with induction failure (p=.0036) while high OPAL1/G0 expression was associated with long term event free survival (p=.02), particularly in males (p=.0004). Interestingly, actual quantitative levels of OPAL1/G0 appeared to be important and there was a clear expression threshold between remission and relapse.

To further validate the role of OPAL1/G0 in outcome prediction in ALL, we tested the usefulness of OPAL1/G0 on two additional independent set of ALL cases, the statistically designed infant ALL cohort described above, and the publicly available St. Jude ALL dataset (Yeoh et al., Cancer Cell 1; 133-143, 2002). In these two data sets, it should be noted that we explored OPAL1/G0's statistics specifically, and (in this context) did not test any other gene. Hence, the significance of the p-values computed for these two additional data sets should not be balanced against a large number of potential candidate genes. There was only one gene considered, and that was OPAL1/G0. Further, the threshold was fixed using the top 22% (17 samples) expressors as the threshold, not optimized as it was in the analysis of the pre-B training set.

Of the 76 members of the infant ALL data set (restricted to no-marginal ALLs), 29 (38%) were classified as CCR (continuous complete remission) while 47 (62%) were classified as FAIL. The following statistics were observed.

Low OPAL1/G0 expression (bottom 78%; 59 samples)

CCR: 19 32%

FAIL: 40 68%

High OPAL1/G0 expression (top 22%; 17 samples)

CCR: 10 59%

FAIL: 7 41%

By Chi-squared: p-value \approx 0.0465

By TNoM: p-value \approx 0.0453

5

For the Downing data set, "Heme Relapse" and "Other Relapse" were classified as FAIL and the 2nd AML was discarded as being of indeterminate outcome. Of the 232 members of the Downing data set, 201 (87%) were classified as CCR (continuous complete remission) while 31 (13%) were classified as FAIL. The following statistics were observed.

10

Low OPAL1/G0 expression (bottom 78%; 181 samples)

CCR: 150 83%

FAIL: 31 17%

15

High OPAL1/G0 expression (top 22%; 51 samples)

CCR: 51 100%

FAIL: 0 0%

20

By Chi-squared: p-value \approx 0.0014

TNoM is NA because same majority class in both groups

An additional result against the Downing data set is that if the threshold is lowered slightly to include in the high group the top 25% of expressors (that is, 8 additional cases are above the OPAL1/G0 threshold), we obtained:

25

Low OPAL1/G0 expression (bottom 75%; 173 samples)

CCR: 142 82%

FAIL: 31 18%

30

High OPAL1/G0 expression (top 25%; 59 samples)

CCR: 59 100%

FAIL: 0 0%

By Chi-squared: $p\text{-value} \approx 0.0004$

TNoM is NA because same majority class in both groups

5 The more reflective p-value apparently lies closer to $p = 0.0004$ than to 0.0014, since the threshold point is only a small distance from the predetermined 22% point and is characterized by a large gap in OPAL1/G0 expression values.

10 It should be noted that all three of these data sets are totally disjoint, and as a result the latter two studies represent independent validation of the statistics observed in the original "pre-B" training set evaluation. As previously discussed, Yeoh et al. were not able to identify or validate genes associated with outcome in the St. Jude dataset. The St. Jude data set was not balanced for remission versus failure; the overall long term remission rate in this series of cases was 87%. Additionally, Yeoh et al. employed SVMs which included many genes in the classification that masked the significance of OPAL1/G0. Our adapted BD metric controlled model complexity and allowed the significance of OPAL1/G0 to be realized in this data set. Indeed, we found that 100% of the cases in this St. Jude series with higher levels of OPAL1/G0, regardless of karyotype, achieved long term remissions ($p=0.0014$).

20 The following represents a breakdown of OPAL1/G0 expression statistics within various subpopulations of the Downing data set. The OPAL1/G0 threshold (25%) obtained by optimization in the original pre-B training set analysis was used. This yields 59 high OPAL/G0 cases in total, which are distributed among the various subgroups as follows:

25 TEL-AML1 (61 members)

Outcome statistics

57 CCR 93%

4 FAIL 7%

30 Low OPAL1/G0 expression (7 samples)

3 CCR 43%

4 FAIL 57%

High OPAL1/G0 expression (54 samples)

54 CCR 100%

0 FAIL 0%

5

Hyperdiploid > 50 (48 samples)

Outcome statistics

43 CCR 90%

10

5 FAIL 10%

Low OPAL1/G0 expression (46 samples)

41 CCR 89%

5 FAIL 11%

15

High OPAL1/G0 expression

2 CCR 100%

0 FAIL 0%

20 Hyperdiploid 47-50 (19 members)

Outcome statistics

19 CCR 100%

0 FAIL 0%

25

Low OPAL1/G0 expression (18 samples)

18 CCR 100%

0 FAIL 0%

30

High OPAL1/G0 expression (1 sample)

1 CCR 100%

0 FAIL 0%

Pseudodiploid (21 members)

Outcome statistics

5 19 CCR 90%
 2 FAIL 10%

Low OPAL1/G0 expression (19 samples)

 17 CCR 89%
 2 FAIL 11%
10

High OPAL1/G0 expression (2 samples)

 2 CCR 100%
 0 FAIL 0%

15 As noted above, these data support the association of OPAL1/G0 with outcome across biological classifications, as noted above for the pre-B training set.

Cloning and Characterization of OPAL1/G0

 The human homologue of OPAL1/G0 was fully cloned and its genomic
20 structure characterized. OPAL1/G0 is highly conserved among eukaryotes, maps to
human chromosome 10q24, and appears to be a novel, potentially transmembrane
signaling protein. To clone OPAL1/G0, RACE PCR was used to clone upstream
sequences in the cDNA using lymphoid cell line RNAs. The genomic structure was
derived from a comparison of OPAL1/G0 cDNAs to contiguous clones of germline
25 DNA in GenBank. The total predicted mRNA length is approximately 4 kb (Fig. 2C;
SEQ ID NO:16). We have developed very specific primers and probes to measure
OPAL1/G0 (as well as G1 and G2) (see Example III) both qualitatively and
quantitatively using PCR techniques.

 Interestingly, preliminary studies reveal that the gene for OPAL1/G0 encodes
30 two different RNAs (and potentially up to five different RNAs through alternative
splicing of upstream exons) and presumably two different proteins based on
alternative use of 5' exons (1a and 1). These two different transcripts are differentially
expressed in leukemia cell lines.

Fig.5 is schematic drawing of the structure of OPAL1/G0. OPAL1/G0 is encoded by four different exons and was cloned using RACE PCR from the 3' end of the gene using the Affymetrix oligonucleotide probe sequence (38652_at); interestingly the oligonucleotide (overlining labeled "Affy probes") designed by Affymetrix from EST sequences turns out to be in the extreme 3' untranslated region of this novel gene. The predicted coding region is shown as underlining for each exon. The location of primers we developed for use in quantitative detection of transcripts are shown as arrows above the exons.

Interestingly, OPAL1/G0 appears to encode at least two different proteins through alternative splicing of different 5' exons (1 and 1a). Fig. 2A shows the nucleotide sequence (SEQ ID NO:1) and putative amino acid sequence (SEQ ID NO:2) of OPAL1/G0.(including exon 1), and Fig. 2B shows the nucleotide sequence (SEQ ID NO:3) and putative amino acid sequence (SEQ ID NO:4) of OPAL1/G0 (including exon 1a).

Table 3 shows the results of RT-PCR assays performed in accordance with Example III that confirm alternative exon use in OPAL1/G0. While all leukemia cell lines (REH, SUPB15) contained an OPAL1/G0 transcript with exons 2-3 and with exon 1a fused to exon 2; only ½ of the cell lines and the primary human ALL samples isolated to date express the alternative transcript (exon 1 fused to exon 2).

Table 3. RT-PCR assays of alternative exon use in OPAL1/G0.

Cell line	G0		
	exon 1-2	exon1a- 2	exon 2-3
SUPB15 t(9;22) e1a2	-	+	+
REH t(12;21)	+	+	+
K562 t(9;22) b3a2	+	+	+
BV173 t(9;22) b2a2	-	+	+
697 t(1;19)	+	+	+
NB-4 t(15;17)	-	+	+
MV411 t(4;11)	+	+	+
size	154	158	166
predicted	148	155	~168
100 ng equivalent RNA into each reaction			

OPAL1/G0 appears to be rather ubiquitously expressed and it has a highly similar murine homologue. Preliminary examination of the translated coding sequence (Fig. 2) reveals a novel protein with a signal peptide, a short sequence (53 amino acids) which may be inserted in either the plasma membrane and be extracellular, or inserted within an intracellular membrane; a potential transmembrane domain; and an intracellular domain. Within the intracellular domain there are proline-rich regions that have strong homologies to proteins that bind WW domains and which are referred to as WW-binding protein 1 (WBP, see above). WW domains mediate interactions between proline-rich transcription factors and cytoplasmic signaling molecules. The data suggest that that this novel gene encodes a signaling protein, which may function as a receptor depending on its cellular location.

Characterization of G1 and G2

G1 encodes an interesting protein, a G protein $\beta 2$ homologue that has been linked to activation of protein kinase C, to inhibition of invasion, and to chemosensitivity in solid tumors. It is also interesting that the Bayesian tree linked G2 (the IL-10 receptor α) to G1 and OPAL1/G0, as the interleukin IL-10 has been previously linked to improved outcome in pediatric ALL (Lauten et al., Leukemia 16:1437-1442, 2002; Wu et al., Blood Abstract, Blood Supplement 2002 (Abstract #3017)). IL-10 has been shown to be an autocrine factor for B cell proliferation and also to suppress T cell immune responses. ALL blasts that express a shortened, alternatively spliced form of IL-10 have been shown to have significantly better 5 year EFS ($p=.01$) (Wu et al., Blood Abstract, Blood Supplement 2002 (Abstract #3017)). We have developed specific primers and probes to assess the direct expression of each of these genes in large ALL cohorts (Example III).

EXAMPLE III.

RT-PCR for Analysis of Expression Levels of OPAL1/G0, G1, G2 and other Genes of Interest

We have developed direct RT-PCR assays to precisely measure the quantitative expression of these genes in an efficient two step approach. First, we perform a "qualitative" screen for positive cases using non-quantitative "end-point" RT-PCR assays with rapid and very inexpensive detection using the Agilent

bioanalyzer. Positive cases detected with this simple, rapid, and highly sensitive methodology are then targeted for precise quantitative assessment of a particular gene using automated quantitative real time RT-PCR (Taqman technology).

Sequences for OPAL1/G0 (both splice forms) and pseudogenes identified from the other chromosomes were aligned, and OPAL1/G0 primers were designed to maximize the differences between the true OPAL1/G0 genes and the pseudogenes. The primers and probe sequences developed for specific quantitative assessment of the two alternatively spliced forms of OPAL1/G0 (assessed by quantifying mRNAs with exon 1 fused to exon 2 or alternatively exon 1a fused to exons 2) are:

For exon 1 or 1a to 2 (the (+) primers are sense and the (-) are antisense)::

Exon 1(+)

CCAACGTTAGTGTGGACGATGC (SEQ ID NO:5)

Exon 1a(+)

GCATGGCGCTCCTGCTC (SEQ ID NO:6)

Exon 2(-)

GTAGTAGTTGCAGCACTGAGACTG (SEQ ID NO:7)

Exon 2 probe (5' FAM/3' TAMRA)

CCACAGCAGTGTCTGTGTCACAGATGTAGC (SEQ ID NO:8)

For exon 2 to 3:

Exon2 (+)a

CAGTCTCAGTGCTGCAACTACTAC (SEQ ID NO:9)

Exon 3(-)

GGCTTCTCGGTAAGCGATCAG (SEQ ID NO:10)

Exon 3 probe (5' FAM/3' TAMRA)

CTCAGGATGATGATGATGGTCCACACCAGCC (SEQ ID NO:11)

Using these primers and probes, we have developed highly sensitive and specific automated quantitative assays for OPAL1/G0 expression over a wide expression range. A standard curve was derived for the automated quantitative RT-PCR assays for the two alternatively spliced forms of OPAL1/G0. The assays were performed in cell lines shown in Table 3 and are highly linear over a large dynamic range.

The primers and probe sequences developed for specific quantitative assessment of G1 (G protein β 2) and G2 (IL10R α) are:

G1: spans 2 introns (1.9 kb and 0.3 kb); from exon 3 to exon 5; 278 bp amplicon

5 G1e3 (+)

CCAAGGATGTGCTGAGTGTGG (SEQ ID NO:12)

G1e5 (-)

CGTGTTCAAGATAGCCTGTGTGG (SEQ ID NO:13)

10 G2: spans 1 intron of 3.6 kb; from exon 3 to exon 4; 189 bp amplicon

G2e3 (+)

CCAAGTGGACCGTCACCAAC (SEQ ID NO:14)

G2e4 (-)

GAATGGCAATCTCATACTCTCGG (SEQ ID NO:15)

15

Automated Quantitative RT-PCR

We routinely develop fluorogenic RT-PCR assays to detect the presence of leukemia-associated human genes, as well as viral genes, using an automated, closed analysis system (ABI 7700 Sequence Detector, PE-Applied Biosystems Inc., Foster City, CA). Accurate standards of cloned cDNAs containing the gene or sequence of interest are prepared in plasmid vectors (pCR 2.1, Invitrogen). These standard reagents are quantitated by fluorescence spectrometry and serially diluted over a six log range. Quantitative PCR is carried out in triplicate in the ABI 7700 instrument in a 96 well plate format, with optimized PCR conditions for each assay. The reverse transcriptase reaction employs 1 μ g of RNA in a 20 μ l volume consisting of 1x Perkin Elmer Buffer II, 7.5 mM MgCl₂, 5 μ M random hexamers, 1 mM dNTP, 40U RNasin and 100U MMLV reverse transcriptase. The reaction is performed at 25°C for 10 minutes, 48°C for 60 min and 95°C for 10 min. 4.5 μ l of the resulting cDNA is used as template for the PCR. This is added to 1X Taqman Universal PCR Master Mix (PE Applied Biosystems, Foster City, CA), 100 nM fluorescently labeled Taqman probe and 100 nM of each primer in a 50 μ l volume. The PCR is performed in the PRISM 7700 Sequence Detector as follows: "hot start" for 10 minutes at 95°C (with AmpliTaq Gold, Perkin-Elmer) then 40 two step cycles of 95°C for 15 seconds and

60°C for 1 minute. This system detects the level of fluorescence from cleaved probe during each cycle of PCR and constructs the data into an amplification plot. This displays the threshold cycle (C_T) of detection for each reaction. The data collection and analysis are performed with Sequence Detection System v.1.6.3 software (PE Applied Biosystems, Foster City, CA). A standard concentration curve of C_T versus initial cDNA quantity is generated and analyzed with the ABI software to confirm the sensitivity range and reproducibility of the assay. To confirm RNA integrity, a segment of the ubiquitously expressed E2A gene is also amplified in all patient samples, along with a standard E2A or GAPDH cloned cDNA dilution series. This method can be utilized to quantitatively analyze expression levels for any gene of interest.

EXAMPLE IV

Supervised Methods for Prediction of Outcome in Pediatric ALL

Discretization

First the preB training set was discretized using a supervised method as well as an unsupervised discretization. Next p-values were computed by using the formula $(nr/nh - er)/(er*(1-er))$ then determine the likelihood of this value in a t-distribution. Here nr = number of remissions for gene high, nh = number of cases with gene high, and er = expected value of remission (44%). The results were ranked according to this p-value, and the preB training set was compared to entire preB data set. The results are shown in Tables 4-7. Tables 4 and 6 show two different lists based on the training set; Tables 5 and 7 show the entire preB data set for each of the two different approaches, respectively. Note that OPAL1/G0 is included on each of these lists as correlated with outcome, and there is substantial overlap between and among the lists. These lists thus identify potential additional genes that may be associated with OPAL1/G0 metabolically, might help determine the mechanism through which OPAL1/G0 acts, and might identify additional therapeutic or diagnostic genes.

Cumulative Distribution Functions (CDFs)

First the Helman-Veroff normalization scheme was applied to the preB training set data. Then CDFs were computed, followed by average and maximum

difference between the CDFs. The distance between the two CDF curves reflects how different the two distributions are, hence the maximum distance and the average distance are measures of the way the two set differed. Finally, the genes were ranked by average and maximum differences for pre B training set and the entire preB data set. The results are shown in Tables 8-11.

The relative expression level for Affymetrix probe 39418_at (i.e., 0.5 = half the median) was plotted across our pediatric ALL cases organized by outcome: FAIL (left panel) or REM (right panel), using Genespring (Silicon Genetics). The results showed that this gene's relative expression appears to be higher across failure cases and lower across remission cases.

Affymetrix probe 39418_at appears to be a probe from the consensus sequence of the cluster AJ007398, which includes *Homo sapiens* mRNA for the PBK1 protein (Huch et al., Placenta 19:557-567 (1998)). The sequence's approved gene symbol is DKFZP564M182, and the chromosomal location is 16p13.13.

Originally, PBK1 was discovered through the identification of differentially expressed genes in human trophoblast cells by differential-display RT-PCR. Functional annotations for the gene that this probe seems to represent are incomplete, however the sequence appears to have a protein domain similar to the ribosomal protein L1 (the largest protein from the large ribosomal subunit). PBK1 may prove to be a useful therapeutic target for treatment of pediatric ALL.

Table 4 – Discretization/Training Set #1

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.000005	86.11	36		38652_at	****NM_017787 hypothetical protein FLJ20367 NM_017787 hypothetical protein FLJ20367
0.000463	68.75	48		36012_at	NM_006346 analysis PIBF1 gene product
0.000493	71.79	39	602731	41819_at	NM_001465 analysis FYN-binding protein FYB-120/130
0.000579	80	25	602982	38203_at	NM_002248 analysis potassium intermediate/small conductance calcium-activated channel subfamily N member 1
0.000611	73.53	34	603501	38270_at	NM_003631 analysis poly ADP-ribose glycohydrolase
0.000637	65.52	58		38838_at	NM_005033 analysis polymyositis/scleroderma autoantigen 1 75kD
0.000677	72.22	36		32224_at	NM_014824 analysis KIAA0769 gene product
0.000687	68.09	47	604076	36295_at	NM_003435 analysis zinc finger protein 134 clone pHZ-15
0.000744	71.05	38	605072	35756_at	NM_005716 analysis GLUT1 C-terminal binding protein
0.000783	81.82	22		39357_at	
0.000785	66.67	51		41559_at	
0.000925	64.91	57	603026	38134_at	NM_002655 analysis pleiomorphic adenoma gene 1
0.001017	67.39	46	602600	32398_s_at	NM_004631 analysis low density lipoprotein receptor-related protein 8 apolipoprotein e receptor NM_017522 analysis apolipoprotein E receptor 2
0.001146	75	28		39833_at	NM_015716 analysis Misshapen/NIK-related kinase
0.001151	66	50		41727_at	NM_016284 analysis KIAA1007 protein
0.001389	78.26	23		41192_at	NM_019610 analysis hypothetical protein 669
0.001408	67.44	43		35669_at	
0.001413	71.88	32	604463	33111_at	NM_007053 analysis natural killer cell receptor immunoglobulin superfamily member
0.001441	87.5	16		39768_at	
0.001549	70.59	34		36537_at	
0.001681	65.31	49	603303	31473_s_at	NM_003747 analysis tankyrase TRF1-interacting ankyrin-related ADP-ribose polymerase
0.001741	61.11	72		32624_at	
0.001741	61.11	72	147267	37343_at	NM_002224 analysis inositol 1 4 5-triphosphate receptor type 3
0.00182	68.42	38	137140	37062_at	NM_000807 analysis gamma-aminobutyric acid A receptor alpha 2 precursor
0.00182	68.42	38	604092	572_at	NM_003318 analysis TTK protein kinase
0.001929	63.64	55	152390	307_at	NM_000698 analysis arachidonate 5-lipoxygenase
0.00226	86.67	15	251000	40105_at	NM_000255 analysis methylmalonyl Coenzyme A mutase precursor
0.002336	69.7	33	136533	40570_at	NM_002015 analysis forkhead box O1A
0.002381	60.87	69	300304	40141_at	NM_003588 analysis cullin 4B

Alpha (p-value)	Percent Remission High	Number Patients	High Link	Omin Link	Affy Id	Description
0.002419	75	24	<u>107265</u>	1116_at	NM_001770	analysis CD19 antigen
0.002419	75	24	<u>194550</u>	40569_at	NM_003422	analysis zinc finger protein 42 myeloid-specific retinoic acid- responsive
0.002447	64.58	48	<u>602545</u>	1488_at	NM_002844	analysis protein tyrosine phosphatase receptor type K
0.002526	68.57	35		38821_at	NM_006320	analysis progesterone membrane binding protein
0.002694	73.08	26		40177_at		
0.002712	67.57	37	<u>313650</u>	112_g_at	NM_004606	analysis TATA box binding protein TBP associated factor RNA polymerase II A 250kD
0.002712	67.57	37		1756_f_at	NM_000776	analysis cytochrome P450 subfamily IIIA niphedipine oxidase polypeptide 3
0.002712	67.57	37	<u>600310</u>	40161_at	NM_000095	analysis cartilage oligomeric matrix protein presursor
0.002712	67.57	37	<u>230000</u>	41814_at	NM_000147	analysis fucosidase alpha-L- 1 tissue
0.002776	57.73	97	<u>191318</u>	32557_at	NM_007279	analysis U2 small nuclear ribonucleoprotein auxiliary factor 65kD
0.002863	62.5	56	<u>601958</u>	34726_at	NM_000725	analysis calcium channel voltage-dependent beta 3 subunit

Table 4 – Discretization/Training Set #1 (continued)

Table 5 – Discretization/Whole Set #1

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.000102	75.61	41	<u>602982</u>	38203_at	NM_002248 analysis potassium intermediate/small conductance calcium-activated channel subfamily N member 1
0.000118	71.15	52		38652_at	***NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
0.000213	64.2	81	<u>162096</u>	577_at	NM_002391 analysis midkine neurite growth-promoting factor 2
0.000275	64.47	76	<u>604076</u>	36295_at	NM_003435 analysis zinc finger protein 134 clone pHZ-15
0.000369	59.83	117	<u>147267</u>	37343_at	NM_002224 analysis inositol 1 4 5-triphosphate receptor type 3
0.000379	61.96	92		38838_at	NM_005033 analysis polymyositis/scleroderma autoantigen 1 75kD
0.000382	66.67	60		35669_at	
0.000391	64	75		41727_at	NM_016284 analysis KIAA1007 protein
0.000474	74.29	35		38713_at	NM_019106 analysis septin 3
0.000584	60.61	99	<u>602731</u>	41819_at	NM_001465 analysis FYN-binding protein FYB-120/130
0.000588	65.57	61	<u>604463</u>	33111_at	NM_007053 analysis natural killer cell receptor immunoglobulin superfamily member
0.000622	65.08	63	<u>118820</u>	41252_s_at	NM_020991 analysis chorionic somatomammotropin hormone 2 isoform 1 precursor NM_022644 analysis chorionic somatomammotropin hormone 2 isoform 2 precursor NM_022645 analysis chorionic somatomammotropin hormone 2 isoform 3 precursor NM_022646 analysis chori
0.000651	70.73	41		1756_f_at	NM_000776 analysis cytochrome P450 subfamily IIIA niphedipine oxidase polypeptide 3
0.000651	70.73	41		40177_at	
0.000667	61.9	84	<u>602026</u>	32724_at	NM_006214 analysis phytanoyl-CoA hydroxylase Refsum disease
0.000709	66.67	54	<u>145505</u>	40617_at	NM_005622 analysis SA rat hypertension-associated homolog
0.000753	63.38	71		41559_at	
0.000782	60.42	96	<u>601798</u>	34332_at	NM_005471 analysis glucosamine-6-phosphate isomerase
0.000784	63.01	73		36129_at	
0.000873	62.03	79	<u>603261</u>	35741_at	NM_003559 analysis phosphatidylinositol-4-phosphate 5-kinase type II beta
0.000892	64.52	62		32224_at	NM_014824 analysis KIAA0769 gene product
0.000892	64.52	62		35066_g_at	NM_013303 analysis fetal hypothetical protein
0.000928	61.45	83	<u>603303</u>	31473_s_at	NM_003747 analysis tankyrase TRF1-interacting ankyrin-related ADP-ribose polymerase
0.000971	70	40	<u>602793</u>	34156_i_at	NM_003511 analysis H2A histone family member I
0.00101	88.24	17	<u>602015</u>	41068_at	NM_002540 analysis outer dense fibre of sperm tails 2
0.001048	60.22	93		36825_at	NM_006074 analysis stimulated trans-acting factor 50 kDa
0.001063	62.86	70		37814_g_at	

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.001089	59.79	97	<u>300248</u>	36004_at	NM_003639 analysis inhibitor of kappa light polypeptide gene enhancer in B-cells kinase gamma
0.001093	65.45	55	<u>604092</u>	572_at	NM_003318 analysis TTK protein kinase
0.001104	62.5	72		38926_at	
0.001216	61.54	78		41478_at	
0.001225	58.26	115	<u>122561</u>	40650_r_at	NM_004382 analysis corticotropin releasing hormone receptor 1
0.001251	61.25	80	<u>601958</u>	34726_at	NM_000725 analysis calcium channel voltage-dependent beta 3 subunit
0.001324	70.27	37	<u>107265</u>	1116_at	NM_001770 analysis CD19 antigen
0.001333	63.49	63	<u>602597</u>	361_at	NM_004326 analysis B-cell CLL/lymphoma 9
0.001431	59.78	92	<u>300059</u>	34292_at	NM_003492 chromosome X open reading frame 12
0.001431	59.78	92	<u>604518</u>	38865_at	NM_004810 analysis GRB2-related adaptor protein 2
0.001444	62.69	67	<u>602600</u>	32398_s_at	NM_004631 analysis low density lipoprotein receptor-related protein 8
					apolipoprotein e receptor NM_017522 analysis apolipoprotein E receptor 2
0.001455	59.57	94	<u>123838</u>	1923_at	NM_005190 analysis cyclin C
0.001547	61.97	71	<u>103270</u>	40336_at	NM_004110 analysis ferredoxin reductase isoform 2 precursor NM_024417 ferredoxin reductase isoform 1 precursor

Table 5 – Discretization/Whole Set #1 (continued)

Table 6 – Discretization/Training Set #2

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.000326	72.5	40		38652_at	****NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
0.000677	72.22	36 <u>602731</u>		41819_at	
0.001085	66.67	48 <u>152390</u>		307_at	
0.001215	65.38	52		41478_at	NM_000698 analysis arachidonate 5-lipoxygenase
0.002082	66.67	42 <u>137140</u>		37062_at	NM_000807 analysis gamma-aminobutyric acid A receptor alpha 2 precursor
0.002526	68.57	35		32224_at	NM_014824 analysis KIAA0769 gene product
0.002666	63.46	52		39190_s_at	
0.002768	62.96	54		32624_at	
0.003068	65.85	41 <u>602600</u>		32398_s_at	NM_004631 analysis low density lipoprotein receptor-related protein 8 apolipoprotein e receptor
0.003236	65.12	43 <u>601798</u>		34332_at	NM_017522 analysis apolipoprotein E receptor 2
0.003236	65.12	43 <u>601974</u>		587_at	NM_005471 analysis glucosamine-6-phosphate isomerase
0.003547	63.83	47 <u>300059</u>		34292_at	NM_001400 analysis endothelial differentiation sphingolipid G-protein-coupled receptor 1
0.004271	65.79	38		35669_at	NM_003492 chromosome X open reading frame 12
0.004271	65.79	38		36537_at	
0.004502	65	40 <u>600310</u>		40161_at	NM_000095 analysis cartilage oligomeric matrix protein presursor
0.004516	70.37	27 <u>600703</u>		32414_at	
0.005118	63.04	46 <u>605230</u>		1711_at	NM_005657 analysis tumor protein p53-binding protein 1
0.005118	63.04	46 <u>600735</u>		625_at	
0.005625	66.67	33 <u>604090</u>		40575_at	NM_004747 analysis discs large Drosophila homolog 5
0.005962	65.71	35		35260_at	NM_014938 analysis KIAA0867 protein
0.006102	60	60		2091_at	
0.006279	64.86	37 <u>133171</u>		1087_at	NM_000121 analysis erythropoietin receptor precursor
0.006413	58.82	68		31353_f_at	NM_012185 analysis forkhead box E2
0.007559	61.7	47 <u>601920</u>		35414_s_at	NM_000214 analysis jagged 1 precursor
0.007559	61.7	47		41559_at	
0.007755	61.22	49 <u>600074</u>		266_s_at	NM_013230 CD24 antigen small cell lung carcinoma cluster 4 antigen
0.007755	61.22	49		33233_at	
0.008091	60.38	53 <u>309860</u>		37628_at	NM_000898 analysis monoamine oxidase B
0.008466	59.32	59		39865_at	
0.008781	64.71	34 <u>600392</u>		1043_s_at	NM_002879 analysis RAD52 S. cerevisiae homolog
0.008781	64.71	34 <u>130610</u>		36733_at	NM_001961 analysis eukaryotic translation elongation factor 2
0.008781	64.71	34 <u>162096</u>		577_at	NM_002391 analysis midkine neurite growth-promoting factor 2

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.009185	63.89	36 <u>601014</u>	40246_at	NM_004087	analysis discs large Drosophila homolog 1
0.009556	63.16	38	1756_f_at	NM_000776	analysis cytochrome P450 subfamily IIIA niphedipine oxidase polypeptide 3
0.009895	62.5	40 <u>605179</u>	33061_at	NM_001214	analysis chromosome 16 open reading frame 3
0.009895	62.5	40 <u>312820</u>	34068_f_at	NM_005635	analysis synovial sarcoma X breakpoint 1
0.009895	62.5	40	34186_at		
0.010201	61.9	42	32233_at		
0.010478	61.36	44	32978_g_at	NM_015864	analysis PL48
0.010725	60.87	46 <u>601632</u>	35939_s_at	NM_006237	analysis POU domain class 4 transcription factor 1

Table 6 – Discretization/Training Set #2 (continued)

Table 7 – Discretization/Whole Set #2

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.000032	73.58	53	<u>602731</u>	41819_at	NM_001465 analysis FYN-binding protein FYB-120/130
0.000299	66.15	65	<u>601798</u>	34332_at	NM_005471 analysis glucosamine-6-phosphate isomerase
0.000486	67.27	55	<u>162096</u>	577_at	NM_002391 analysis midkine neurite growth-promoting factor 2
0.001104	62.5	72	<u>152390</u>	307_at	NM_000698 analysis arachidonate 5-lipoxygenase
0.001493	65.38	52	<u>600392</u>	1043_s_at	NM_002879 analysis RAD52 S. cerevisiae homolog
0.001738	63.79	58	<u>118820</u>	41252_s_at	NM_020991 analysis chorionic somatomammotropin hormone 2 isoform 1 precursor
					NM_022644 analysis chorionic somatomammotropin hormone 2 isoform 2 precursor
					NM_022645 analysis chorionic somatomammotropin hormone 2 isoform 3 precursor
					NM_022646 analysis chori
0.001927	65.96	47	<u>162096</u>	38124_at	NM_002391 analysis midkine neurite growth-promoting factor 2
0.002265	64.15	53	<u>130610</u>	36733_at	NM_001961 analysis eukaryotic translation elongation factor 2
0.002265	64.15	53		39196_i_at	
0.002431	60	80		36331_at	NM_003286 analysis topoisomerase DNA I
0.002477	59.76	82	<u>126420</u>	34351_at	
0.002572	62.71	59		41559_at	
0.003001	60.87	69	<u>601920</u>	35414_s_at	NM_000214 analysis jagged 1 precursor
0.003098	64	50		32224_at	NM_014824 analysis KIAA0769 gene product
0.003405	66.67	39		35669_at	
0.003739	56.88	109		41727_at	NM_016284 analysis KIAA1007 protein
0.004149	60.29	68		41478_at	
0.004387	59.46	74	<u>603006</u>	1483_at	NM_001794 analysis cadherin 4 type 1 R-cadherin retinal
0.004387	59.46	74	<u>124092</u>	1548_s_at	NM_000572 analysis interleukin 10
0.004572	58.75	80		39190_s_at	
0.004613	62.75	51		1756_f_at	NM_000776 analysis cytochrome P450 subfamily IIIA niphedipine oxidase polypeptide 3
0.004613	62.75	51	<u>601013</u>	33625_g_at	NM_000721 analysis calcium channel voltage-dependent alpha 1E subunit
0.00478	57.78	90		32058_at	NM_004854 analysis HNK-1 sulfotransferase
0.005235	61.02	59	<u>601184</u>	33208_at	NM_006260 analysis DnaJ Hsp40 homolog subfamily C member 3
0.005282	65	40		40177_at	
0.005561	64.29	42	<u>300097</u>	35097_at	NM_002363 analysis melanoma antigen family B 1
0.005602	60	65	<u>147267</u>	37343_at	NM_002224 analysis inositol 1 4 5-triphosphate receptor type 3
0.005803	59.42	69	<u>605230</u>	1711_at	NM_005657 analysis tumor protein p53-binding protein 1
0.005803	59.42	69	<u>300059</u>	34292_at	NM_003492 chromosome X open reading frame 12
0.005826	63.64	44	<u>604090</u>	40575_at	NM_004747 analysis discs large Drosophila homolog 5
0.006398	56.19	105		31353_f_at	NM_012185 analysis forkhead box E2

Alpha (p-value)	Percent Remission High	Number Patients High	Omim Link	Affy Id	Description
0.007277	60.34	58		31653_at	****NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154 NM_007044 analysis katanin p60 subunit A 1
0.007428	60	60		38652_at	
0.007566	59.68	62		32707_at	
0.007566	59.68	62		35602_at	
0.007692	59.38	64	<u>605491</u>	34873_at	NM_006393 analysis nebullette
0.007806	59.09	66		38530_at	NM_002653 analysis paired-like homeodomain transcription factor 1 NM_013303 analysis fetal hypothetical protein
0.007909	58.82	68	<u>602149</u>	37920_at	
0.008012	63.41	41		773_at	
0.008081	58.33	72		35066_g_at	

Table 7 – Discretization/Whole Set #2 (continued)

Table 8 – Maximum Difference-Selected Genes (Training Set)

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
6080	0.350189	0.133728		38652_at	****NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
6031	0.342466	0.133158	142200	38585_at	NM_000559 analysis hemoglobin gamma A
4022	0.339988	0.132256	140555	35965_at	NM_002155 analysis heat shock 70kD protein 6 HSP70B
6674	0.322064	0.130643		39418_at	
5053	0.307928	0.129113	147267	37343_at	NM_002224 analysis inositol 1 4 5-triphosphate receptor type 3
1662	0.306616	0.128926	191318	32557_at	NM_007279 analysis U2 small nuclear ribonucleoprotein auxiliary factor 65kD
7403	0.305159	0.125099	300151	40435_at	
1717	0.304867	0.124241		32624_at	
2290	0.304722	0.120535	156491	33415_at	NM_002512 analysis non-metastatic cells 2 protein NM23B expressed in
8278	0.303119	0.119869		41559_at	
5676	0.300495	0.118728	110750	38119_at	NM_002101 analysis glycophorin C isoform 1 NM_016815 analysis glycophorin C isoform 2
969	0.298892	0.11592		31472_s_at	
6169	0.297727	0.111653	600276	38750_at	NM_000435 analysis Notch Drosophila homolog 3
2429	0.297581	0.110325	300156	33637_g_at	NM_001327 analysis cancer/testis antigen
740	0.295686	0.110118	156491	1980_s_at	NM_002512 analysis non-metastatic cells 2 protein NM23B expressed in
1779	0.294521	0.107107	605031	32703_at	NM_014264 analysis serine/threonine kinase 18
297	0.291023	0.106625	187011	1403_s_at	NM_002985 analysis small inducible cytokine A5 RANTES
831	0.289857	0.105829		2091_at	
4509	0.288254	0.104053	146691	36624_at	NM_000884 analysis IMP inosine monophosphate dehydrogenase 2
580	0.286797	0.103697	601645	176_at	NM_002719 analysis protein phosphatase 2 regulatory subunit B B56 gamma isoform
6199	0.286797	0.103514	600673	38794_at	NM_014233 analysis upstream binding transcription factor RNA polymerase I
93	0.286797	0.103116		1126_s_at	
5558	0.286651	0.100579	133171	37986_at	NM_000121 analysis erythropoietin receptor precursor
4335	0.285194	0.10045	602524	36386_at	NM_002610 analysis pyruvate dehydrogenase kinase isoenzyme 1
6259	0.281988	0.100437	604518	38865_at	NM_004810 analysis GRB2-related adaptor protein 2
3749	0.281988	0.09987	142704	35606_at	NM_002112 analysis histidine decarboxylase
813	0.280822	0.099596	602867	2062_at	NM_001553 analysis insulin-like growth factor binding protein 7
8219	0.27747	0.099577		41478_at	
5380	0.276159	0.098971		37748_at	
54	0.276013	0.097783	600210	106_at	NM_004350 analysis runt-related transcription factor 3
4892	0.275867	0.097033	604713	37147_at	NM_002975 analysis stem cell growth factor lymphocyte secreted C-type lectin
8012	0.274847	0.09695		41208_at	
5668	0.274556	0.096929	118661	38111_at	NM_004385 analysis chondroitin sulfate proteoglycan 2 versican
7036	0.27441	0.096861		39932_at	

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
8435	0.27441	0.096558	603413	41761_at	NM_003252 analysis TIA1 cytotoxic granule-associated RNA-binding protein-like 1 isoform 1
					NM_022333 TIA1 cytotoxic granule-associated RNA-binding protein-like 1 isoform 2
4051	0.273244	0.09647		36002_at	NM_014939 analysis KIAA1012 protein
537	0.272952	0.096296	605230	1711_at	NM_005657 analysis tumor protein p53-binding protein 1
8601	0.271349	0.096014	600258	525_g_at	NM_000534 analysis postmeiotic segregation 1
3498	0.270329	0.096003	603083	35201_at	NM_001533 analysis heterogeneous nuclear ribonucleoprotein L
1619	0.270184	0.095026		324_f_at	

Table 8 – Maximum Difference-Selected Genes (Training Set) (continued)

Table 9 – Average Difference-Selected Genes (Training Set)

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
54	0.350189	0.133728	600210	106_at	NM_004350 analysis runt-related transcription factor 3
8702	0.342466	0.133158	182120	671_at	NM_003118 analysis secreted protein acidic cysteine-rich osteonectin
5676	0.339988	0.132256	110750	38119_at	NM_002101 analysis glycophorin C isoform 1 NM_016815 analysis glycophorin C isoform 2
8219	0.322064	0.130643		41478_at	
3899	0.307928	0.129113		35796_at	NM_007284 analysis protein tyrosine kinase 9-like A6-related protein
6674	0.306616	0.128926		39418_at	
4801	0.305159	0.125099		37006_at	NM_006425 analysis step II splicing factor SLU7
8799	0.304867	0.124241	605482	824_at	NM_004832 analysis glutathione-S-transferase like
6327	0.304722	0.120535		38971_r_at	NM_006058 analysis Nef-associated factor 1
6080	0.303119	0.119869		38652_at	****NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
7348	0.300495	0.118728	139314	40365_at	NM_002068 analysis guanine nucleotide binding protein G protein alpha 15 Gq class
8479	0.298892	0.11592	602731	41819_at	NM_001465 analysis FYN-binding protein FYB-120/130
4892	0.297727	0.11653	604713	37147_at	NM_002975 analysis stem cell growth factor lymphocyte secreted C-type lectin
7693	0.297581	0.110325	601323	40817_at	NM_006184 analysis nucleobindin 1
2488	0.295686	0.110118	603593	33731_at	NM_003982 analysis solute carrier family 7 cationic amino acid transporter y system member 7
906	0.294521	0.107107	152390	307_at	NM_000698 analysis arachidonate 5-lipoxygenase
6311	0.291023	0.106625	603109	38944_at	NM_005902 analysis MAD mothers against decapentaplegic Drosophila homolog 3
2097	0.289857	0.105829		33188_at	NM_014337 analysis peptidylprolyl isomerase cyclophilin like 2
1779	0.288254	0.104053	605031	32703_at	NM_014264 analysis serine/threonine kinase 18
1570	0.286797	0.103697	602600	32398_s_at	NM_004631 analysis low density lipoprotein receptor-related protein 8 apolipoprotein e receptor
6790	0.286797	0.103514		39607_at	NM_017522 analysis apolipoprotein E receptor 2
489	0.286797	0.103116	602130	1637_at	NM_015458 analysis DKFZP434K171 protein
2989	0.286651	0.100579	602919	34433_at	NM_004635 analysis mitogen-activated protein kinase-activated protein kinase 3
8609	0.285194	0.10045	142230	538_at	NM_001381 analysis docking protein 1
4464	0.281988	0.100437		36576_at	NM_001773 analysis CD34 antigen
7403	0.281988	0.09987	300151	40435_at	NM_004893 analysis H2A histone family member Y
5779	0.280822	0.099596	603501	38270_at	
8670	0.27747	0.099577	600735	625_at	NM_003631 analysis poly ADP-ribose glycohydrolase
4693	0.276159	0.098971	130410	36881_at	NM_001985 analysis electron-transfer-flavoprotein beta polypeptide
7513	0.276013	0.097783	136533	40570_at	NM_002015 analysis forkhead box O1A
1004	0.275867	0.097033	603624	31527_at	NM_002952 analysis ribosomal protein S2
316	0.274847	0.09695	603109	1433_g_at	NM_005902 analysis MAD mothers against decapentaplegic Drosophila homolog 3
5308	0.274556	0.096929	125290	37674_at	NM_000688 analysis aminolevulinate delta- synthase 1

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
1385	0.27441	0.096861	602362	32151_at	NM_002883 analysis Ran GTPase activating protein 1
7036	0.27441	0.096558		39932_at	
2132	0.273244	0.09647		33233_at	
4100	0.272952	0.096296	604857	36060_at	NM_003136 analysis signal recognition particle 54kD
528	0.271349	0.096014	602520	1698_g_at	NM_002757 analysis mitogen-activated protein kinase kinase 5
4643	0.270329	0.096003	604704	36812_at	NM_003567 analysis breast cancer antiestrogen resistance 3
4312	0.270184	0.095026	138322	36336_s_at	NM_002085 analysis glutathione peroxidase 4

Table 9 – Average Difference-Selected Genes (Training Set) (continued)

Table 10 – Maximum Difference-Selected Genes (Whole Set)

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
4975	0.383929	0.133728	300051	37251_s_at	NM_000559 analysis hemoglobin gamma A NM_002155 analysis heat shock 70kD protein 6 HSP70B NM_000435 analysis Notch Drosophila homolog 3 NM_002224 analysis inositol 1 4 5-triphosphate receptor type 3
6031	0.357143	0.133158	142200	38585_at	
4022	0.305332	0.132256	140555	35965_at	
6169	0.305308	0.130643	600276	38750_at	
5053	0.295397	0.129113	147267	37343_at	NM_007279 analysis U2 small nuclear ribonucleoprotein auxiliary factor 65kD NM_004395 analysis drebrin 1 NM_000073 analysis CD3G gamma precursor NM_014233 analysis upstream binding transcription factor RNA polymerase I
6674	0.290241	0.128926		39418_at	
1662	0.288984	0.125099	191318	32557_at	
5554	0.27578	0.124241	126660	37981_at	
6530	0.26748	0.120535	186740	39226_at	NM_001327 analysis cancer/testis antigen NM_001465 analysis FYN-binding protein FYB-120/130 NM_002391 analysis midkine neurite growth-promoting factor 2
6199	0.263078	0.119869	600673	38794_at	
2429	0.262701	0.118728	300156	33637_g_at	
8479	0.262575	0.11592	602731	41819_at	
1054	0.261318	0.111653	156350	31623_f_at	NM_002512 analysis non-metastatic cells 2 protein NM23B expressed in NM_004893 analysis H2A histone family member Y NM_004854 analysis HNK-1 sulfotransferase NM_002345 analysis lumican NM_007359 analysis MLN51 protein
8635	0.259557	0.110325	162096	577_at	
93	0.259306	0.110118		1126_s_at	
2290	0.2583	0.107107	156491	33415_at	
4464	0.257671	0.106625		36576_at	NM_002298 analysis L-plastin NM_005471 analysis glucosamine-6-phosphate isomerase NM_018834 analysis matrin 3 NM_000732 analysis CD3D antigen delta polypeptide TIT3 complex NM_003639 analysis inhibitor of kappa light polypeptide gene enhancer in B-cells kinase gamma NM_016143 analysis p47
1312	0.25742	0.105829		32058_at	
6010	0.256288	0.104053		38549_at	
5600	0.251383	0.103697	600616	38038_at	
5919	0.250377	0.103514		38437_at	NM_002298 analysis L-plastin NM_005471 analysis glucosamine-6-phosphate isomerase NM_018834 analysis matrin 3 NM_000732 analysis CD3D antigen delta polypeptide TIT3 complex NM_003639 analysis inhibitor of kappa light polypeptide gene enhancer in B-cells kinase gamma NM_016143 analysis p47
4308	0.247611	0.103116		36331_at	
4812	0.244341	0.100579	153430	37023_at	
2907	0.243587	0.10045	601798	34332_at	
5315	0.241574	0.100437	604706	37681_i_at	NM_000732 analysis CD3D antigen delta polypeptide TIT3 complex NM_003639 analysis inhibitor of kappa light polypeptide gene enhancer in B-cells kinase gamma NM_016143 analysis p47 NM_014264 analysis serine/threonine kinase 18 NM_001533 analysis heterogeneous nuclear ribonucleoprotein L NM_020310 analysis MAX binding protein
5458	0.241071	0.09987	147120	37864_s_at	
5820	0.240568	0.099596	186790	38319_at	
4053	0.240443	0.099577	300248	36004_at	
2590	0.239185	0.098971		33857_at	NM_000732 analysis CD3D antigen delta polypeptide TIT3 complex NM_003639 analysis inhibitor of kappa light polypeptide gene enhancer in B-cells kinase gamma NM_016143 analysis p47 NM_014264 analysis serine/threonine kinase 18 NM_001533 analysis heterogeneous nuclear ribonucleoprotein L NM_020310 analysis MAX binding protein
1779	0.238179	0.097783	605031	32703_at	
3498	0.237425	0.097033	603083	35201_at	
3455	0.236796	0.09695	603039	35145_at	
1861	0.236293	0.096929	186930	32794_g_at	NM_002101 analysis glycophorin C isoform 1 NM_016815 analysis glycophorin C isoform 2
5676	0.236293	0.096861	110750	38119_at	

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
702	0.236167	0.096558	123838	1923_at	NM_005190 analysis cyclin C
4360	0.235161	0.09647		36434_r_at	
2244	0.234406	0.096296		33362_at	NM_006449 analysis Cdc42 effector protein 3
7206	0.234406	0.096014	601062	40150_at	NM_004175 analysis small nuclear ribonucleoprotein D3 polypeptide 18kD
813	0.234029	0.096003	602867	2062_at	NM_001553 analysis insulin-like growth factor binding protein 7
8485	0.233023	0.095026		41825_at	

Table 10 – Maximum Difference-Selected Genes (Whole Set) (continued)

Table 11 – Average Difference-Selected Genes (Whole Set)

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
54	0.383929	0.133728	600210	106_at	NM_004350 analysis runt-related transcription factor 3
8702	0.357143	0.133158	182120	671_at	NM_003118 analysis secreted protein acidic cysteine-rich osteonectin
5676	0.305332	0.132256	110750	38119_at	NM_002101 analysis glycophorin C isoform 1 NM_016815 analysis glycophorin C isoform 2
8219	0.30508	0.130643		41478_at	
3899	0.295397	0.129113		35796_at	NM_007284 analysis protein tyrosine kinase 9-like A6-related protein
6674	0.290241	0.128926		39418_at	
4801	0.288984	0.125099		37006_at	NM_006425 analysis step II splicing factor SLU7
8799	0.27578	0.124241	605482	824_at	NM_004832 analysis glutathione-S-transferase like
6327	0.26748	0.120535		38971_r_at	NM_006058 analysis Nef-associated factor 1
6080	0.263078	0.119869		38652_at	****NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
7348	0.262701	0.118728	139314	40365_at	NM_002068 analysis guanine nucleotide binding protein G protein alpha 15 Gq class
8479	0.262575	0.11592	602731	41819_at	NM_001465 analysis FYN-binding protein FYB-120/130
4892	0.261318	0.111653	604713	37147_at	NM_002975 analysis stem cell growth factor lymphocyte secreted C-type lectin
7693	0.259557	0.110325	601323	40817_at	NM_006184 analysis nucleobindin 1
2488	0.259306	0.110118	603593	33731_at	NM_003982 analysis solute carrier family 7 cationic amino acid transporter y system member 7
906	0.2583	0.107107	152390	307_at	NM_000698 analysis arachidonate 5-lipoxygenase
6311	0.257671	0.106625	603109	38944_at	NM_005902 analysis MAD mothers against decapentaplegic Drosophila homolog 3
2097	0.25742	0.105829		33188_at	NM_014337 analysis peptidylprolyl isomerase cyclophilin like 2
1779	0.256288	0.104053	605031	32703_at	NM_014264 analysis serine/threonine kinase 18
1570	0.251383	0.103697	602600	32398_s_at	NM_004631 analysis low density lipoprotein receptor-related protein 8 apolipoprotein e receptor
6790	0.250377	0.103514		39607_at	NM_017522 analysis apolipoprotein E receptor 2
489	0.247611	0.103116	602130	1637_at	NM_015458 analysis DKFZP434K171 protein
2989	0.244341	0.100579	602919	34433_at	NM_004635 analysis mitogen-activated protein kinase-activated protein kinase 3
8609	0.243587	0.10045	142230	538_at	NM_001381 analysis docking protein 1
4464	0.241574	0.100437		36576_at	NM_001773 analysis CD34 antigen
7403	0.241071	0.09987	300151	40435_at	NM_004893 analysis H2A histone family member Y
5779	0.240568	0.099596	603501	38270_at	NM_003631 analysis poly ADP-ribose glycohydrolase
8670	0.240443	0.099577	600735	625_at	
4693	0.239185	0.098971	130410	36881_at	NM_001985 analysis electron-transfer-flavoprotein beta polypeptide
7513	0.238179	0.097783	136533	40570_at	NM_002015 analysis forkhead box O1A
1004	0.237425	0.097033	603624	31527_at	NM_002952 analysis ribosomal protein S2
316	0.236796	0.09695	603109	1433_g_at	NM_005902 analysis MAD mothers against decapentaplegic Drosophila homolog 3
5308	0.236293	0.096929	125290	37674_at	NM_000688 analysis aminolevulinate delta- synthase 1

Index	Max Diff	Avg Diff	Omim Link	Affy Id	Description
1385	0.236293	0.096861	602362	32151_at	NM_002883 analysis Ran GTPase activating protein 1
7036	0.236167	0.096558		39932_at	
2132	0.235161	0.09647		33233_at	
4100	0.234406	0.096296	604857	36060_at	NM_003136 analysis signal recognition particle 54kD
528	0.234406	0.096014	602520	1698_g_at	NM_002757 analysis mitogen-activated protein kinase kinase 5
4643	0.234029	0.096003	604704	36812_at	NM_003567 analysis breast cancer antiestrogen resistance 3
4312	0.233023	0.095026	138322	36336_s_at	NM_002085 analysis glutathione peroxidase 4

Table 11 – Average Difference-Selected Genes (Whole Set) (continued)

EXAMPLE V.

SVM Analysis of Pre-B ALL Cohort Data to Discriminate Between Remission and Failure and Among Various Karyotypes

5 We applied linear SVM, SVM with recursive feature elimination (SVM-RFE), and nonlinear SVM methods (polynomial and gaussian) to the pre B training dataset to get a list of genes associated with CCR/Fail. Table 12 shows the top 40 genes for evaluating remission from failure (CCR vs. FAIL). However, CCR vs. FAIL was nonseparable using these methods.

10 We also used SVM-RFE to discriminate between members of the data set who have the certain MLL translocations from those who do not. Table 13 shows the top 40 genes found to discriminate t(12;21) from not t(12;21) (we excluded patients without t(12;21) data from this analysis). Table 14 shows the top 40 genes found to discriminate t(1;19) from not t(1;19). We did not see significant separation for
15 t(9;22), t(4;11) or hyperdiploid karyotypes.

Table 12 -- CCR vs. Fail

38086_at	NM_001542 analysis immunoglobulin superfamily member 3
38652_at	NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
31473_s_at	NM_003747 analysis tankyrase TRF1-interacting ankyrin-related ADP-ribose polymerase
36144_at	
40650_r_at	NM_004382 analysis corticotropin releasing hormone receptor 1
2009_at	NM_004103 analysis protein tyrosine kinase 2 beta
33914_r_at	NM_000140 analysis ferrochelatase
34612_at	NM_004057 analysis calbindin 3
32072_at	NM_005823 analysis megakaryocyte potentiating factor precursor NM_013404 analysis mesothelin isoform 2 precursor
625_at	
33316_at	NM_014729 analysis KIAA0808 gene product
38838_at	NM_005033 analysis polymyositis/scleroderma autoantigen 1 75kD
38539_at	NM_004727 analysis solute carrier family 24 sodium/potassium/calcium exchanger member 1
32503_at	
32930_f_at	NM_014893 analysis KIAA0951 protein
40161_at	NM_000095 analysis cartilage oligomeric matrix protein precursor
38840_s_at	NM_002628 analysis profilin 2
34045_at	
34770_at	NM_005204 analysis mitogen-activated protein kinase kinase kinase 8
36154_at	
38155_at	NM_002553 analysis origin recognition complex subunit 5 yeast homolog like
35842_at	
33946_at	
39213_at	NM_012261 analysis similar to S68401 cattle glucose induced gene
35872_at	NM_000922 analysis phosphodiesterase 3B cGMP-inhibited
38768_at	NM_005327 analysis L-3-hydroxyacyl-Coenzyme A dehydrogenase short chain
32035_at	
36342_r_at	NM_005666 analysis H factor complement like 3
38700_at	NM_004078 analysis cysteine and glycine-rich protein 1
38025_r_at	NM_014961 analysis KIAA0871 protein
36395_at	
39001_at	NM_005918 analysis malate dehydrogenase 2 NAD mitochondrial
33957_at	
36927_at	NM_006820 analysis hypothetical protein expressed in osteoblast
40387_at	NM_001401 analysis endothelial differentiation lysophosphatidic acid G-protein-coupled receptor 2

1368_at	NM_000877	analysis interleukin 1 receptor type I
32551_at	NM_004105	analysis EGF-containing fibulin-like extracellular matrix protein 1 precursor isoform a precursor NM_018894
		analysis EGF-containing fibulin-like extracellular matrix protein 1 isoform b
32655_s_at	NM_006696	analysis thyroid hormone receptor coactivating protein
36339_at		
37946_at	NM_003161	analysis serine/threonine kinase 14 alpha

Table 12 -- CCR vs. Fail (continued)

Table 13 – T (12;21) vs. not T(12;21)

40272_at	NM_001313 analysis collapsin response mediator protein 1
38267_at	NM_004170 analysis solute carrier family 1 neuronal/epithelial high affinity glutamate transporter system Xag member 1
38968_at	NM_004844 analysis SH3-domain binding protein 5 BTK-associated
35019_at	NM_004876 analysis zinc finger protein 254
32227_at	NM_002727 analysis proteoglycan 1 secretory granule
38925_at	NM_003296 analysis testis specific protein 1 probe H4-1 p3-1
41490_at	NM_002765 analysis phosphoribosyl pyrophosphate synthetase 2
35614_at	NM_006602 analysis transcription factor-like 5 basic helix-loop-helix
1211_s_at	NM_003805 analysis CASP2 and RIPK1 domain containing adaptor with death domain
1708_at	NM_002753 analysis mitogen-activated protein kinase 10
39696_at	
40570_at	NM_002015 analysis forkhead box O1A
32778_at	NM_002222 analysis inositol 1 4 5-triphosphate receptor type 1
339_at	NM_001233 analysis caveolin 2
32163_f_at	
40367_at	NM_001200 analysis bone morphogenetic protein 2 precursor
37816_at	NM_001735 analysis complement component 5
35362_at	NM_012334 analysis myosin X
35712_at	
32730_at	
599_at	NM_021958 analysis H2.0 Drosophila like homeo box 1
39827_at	NM_019058 analysis hypothetical protein
1077_at	NM_000448 analysis recombination activating gene 1
36524_at	NM_015320 analysis KIAA1112 protein
39931_at	NM_003582 analysis dual-specificity tyrosine- Y phosphorylation regulated kinase 3
33686_at	
39786_at	
31883_at	NM_002454 analysis methionine synthase reductase isoform 1 NM_024010 methionine synthase reductase isoform 2
38938_at	NM_006593 analysis T-box brain 1
41442_at	NM_005187 analysis core-binding factor runt domain alpha subunit 2 translocated to 3
755_at	NM_002222 analysis inositol 1 4 5-triphosphate receptor type 1
35288_at	NM_015185 analysis Cdc42 guanine exchange factor GEF 9

38578_at	NM_001242 analysis CD27 antigen
37198_r_at	
32343_at	
33910_at	
1089_i_at	
40166_at	NM_018639 analysis CS box-containing WD protein
33494_at	NM_004453 analysis electron-transferring-flavoprotein dehydrogenase
41446_f_at	NM_007372 analysis RNA helicase-related protein

Table 13 – T (12;21) vs. not T(12;21) (continued)

Table 14 – T(1;19) vs. not T(1;19)

1788_s_at	NM_001394 analysis dual specificity phosphatase 4
37680_at	NM_005100 analysis A kinase PRKA anchor protein gravin 12
362_at	NM_002744 analysis protein kinase C zeta
39878_at	NM_020403 analysis cadherin superfamily protein VR4-11
38748_at	NM_001112 analysis RNA-specific adenosine deaminase B1 isoform DRADA2a NM_015833 analysis RNA-specific adenosine deaminase B1 isoform DRABA2b NM_015834 analysis RNA-specific adenosine deaminase B1 isoform DRADA2c
38010_at	NM_004052 analysis BCL2/adenovirus E1B 19kD-interacting protein 3
39614_at	
539_at	NM_002958 analysis RYK receptor-like tyrosine kinase precursor
583_s_at	NM_001078 analysis vascular cell adhesion molecule 1
37967_at	NM_007161 analysis lymphocyte antigen 117
37132_at	NM_014425 analysis inversin
38137_at	NM_003602 analysis FK506-binding protein 6 36kD
40155_at	NM_002313 analysis actin-binding LIM protein 1 isoform a NM_006719 analysis actin-binding LIM protein 1 isoform m NM_006720 analysis actin-binding LIM protein 1 isoform s
38138_at	NM_005620 analysis S100 calcium-binding protein A11
37625_at	NM_002460 analysis interferon regulatory factor 4
35938_at	
35927_r_at	NM_006669 analysis leukocyte immunoglobulin-like receptor subfamily B with TM and ITIM domains member 1
36305_at	NM_001044 analysis solute carrier family 6 neurotransmitter transporter dopamine member 3
36309_at	NM_005259 analysis growth differentiation factor 8
41317_at	NM_021033 analysis RAP2A member of RAS oncogene family
36086_at	NM_001239 analysis cyclin H
36889_at	NM_004106 analysis Fc fragment of IgE high affinity I receptor for gamma polypeptide precursor
37493_at	NM_000395 analysis colony stimulating factor 2 receptor beta low-affinity granulocyte-macrophage
33513_at	NM_003037 analysis signaling lymphocytic activation molecule
40454_at	NM_005245 analysis cadherin family member 7 precursor
38285_at	
307_at	NM_000698 analysis arachidonate 5-lipoxygenase
717_at	NM_021643 analysis GS3955 protein
577_at	NM_002391 analysis midline neurite growth-promoting factor 2
37536_at	NM_004233 analysis CD83 antigen activated B lymphocytes immunoglobulin superfamily
38604_at	NM_000905 analysis neuropeptide Y
951_at	NM_006814 analysis proteasome inhibitor
854_at	NM_001715 analysis B lymphoid tyrosine kinase

31811_r_at	NM_005038 analysis peptidylprolyl isomerase D cyclophilin D
39829_at	NM_005737 analysis ADP-ribosylation factor-like 7
36343_at	NM_012465 tolloid-like 2
36491_at	NM_021992 analysis thymosin beta identified in neuroblastoma cells
37306_at	
33328_at	
35926_s_at	NM_006669 analysis leukocyte immunoglobulin-like receptor subfamily B with TM and ITIM domains member 1

Table 14 – T(1;19) vs. not T(1;19) (continued)

5 We then performed analyses to discriminate CCR vs. FAIL conditioned on various karyotypes (t(12;21), t(1;19), t(9/22), t(4,11) and hyperdiploid (Tables 15-19). Although the results are marginal, the associated gene lists may be useful in risk classification and/or the development of therapeutic strategies.

Table 15 -- CCR/Fail Conditioned on T(12;21)

41093_at	NM_002545 analysis opioid-binding cell adhesion molecule precursor
38092_at	NM_001430 analysis endothelial PAS domain protein 1
35535_f_at	
32930_f_at	NM_014893 analysis KIAA0951 protein
34142_at	
995_g_at	NM_002845 analysis protein tyrosine phosphatase receptor type mu polypeptide
37187_at	NM_002089 analysis GRO2 oncogene
942_at	NM_004683 analysis regucalcin senescence marker protein-30
37864_s_at	
38227_at	NM_000248 analysis microphthalmia-associated transcription factor
281_s_at	NM_000944 analysis protein phosphatase 3 formerly 2B catalytic subunit alpha isoform calcineurin A alpha
38355_at	NM_004660 analysis DEAD/H Asp-Glu-Ala-Asp/His box polypeptide Y chromosome
37328_at	NM_002664 analysis pleckstrin
33644_at	NM_002395 analysis cytosolic malic enzyme 1
1089_i_at	
417_at	NM_005400 analysis protein kinase C epsilon
39474_s_at	NM_013372 analysis cysteine knot superfamily 1 BMP antagonist 1
34052_at	NM_001980 analysis epimorphin
36838_at	NM_002776 analysis kallikrein 10
961_at	NM_000267 analysis neurofibromin
35405_at	NM_000353 analysis tyrosine aminotransferase
326_i_at	
36395_at	
34824_at	NM_013444 analysis ubiquitin 2
1117_at	NM_001785 analysis cytidine deaminase
40000_f_at	
40727_at	NM_014885 analysis anaphase-promoting complex subunit 10
33400_r_at	NM_001010 analysis ribosomal protein S6
33120_at	NM_002925 analysis regulator of G-protein signaling 10
128_at	NM_000396 analysis cathepsin K pycnodysostosis
39623_at	
353_at	NM_012399 analysis phosphatidylinositol transfer protein beta
38627_at	NM_002126 analysis hepatic leukemia factor
31541_at	
34852_g_at	NM_003600 analysis serine/threonine kinase 15

39627_at	NM_003566 analysis early endosome antigen 1 162kD
1002_f_at	
38938_at	NM_006593 analysis T-box brain 1
33191_at	NM_018121 analysis hypothetical protein FLJ10512
33738_r_at	

Table 15 -- CCR/Fail Conditioned on T(12:21) (continued)

Table 16 -- CCR/Fail on T(1:19)

32901_s_at	NM_001550 analysis interferon-related developmental regulator 1
32018_at	
32746_at	NM_003879 analysis CASP8 and FADD-like apoptosis regulator
1368_at	NM_000877 analysis interleukin 1 receptor type I
31992_f_at	
2083_at	NM_000731 analysis cholecystokinin B receptor
33466_at	
36400_at	
34548_at	NM_000497 analysis cytochrome P450 subfamily XIB steroid 11-beta-hydroxylase polypeptide 1
41714_at	
40303_at	NM_003222 analysis transcription factor AP-2 gamma activating enhancer-binding protein 2 gamma
33730_at	
1800_g_at	NM_005236 analysis excision repair cross-complementing rodent repair deficiency complementation group 4
1485_at	NM_004440 analysis EphA7
36873_at	
41871_at	NM_006474 analysis lung type-I cell membrane-associated glycoprotein isoform 2 precursor NM_013317 analysis lung type-I cell membrane-associated glycoprotein isoform 1
607_s_at	NM_000552 analysis von Willebrand factor precursor
41385_at	NM_012307 analysis erythrocyte membrane protein band 4.1-like 3
39102_at	NM_013296 analysis LGN protein
32671_at	NM_014640 analysis KIAA0173 gene product
34714_at	NM_015474 analysis DKFZP564A032 protein
36419_at	
36595_s_at	NM_001482 analysis glycine amidinotransferase L-arginine glycine amidinotransferase
38552_f_at	NM_018844 analysis B-cell receptor-associated protein BAP29
40031_at	NM_000691 analysis aldehyde dehydrogenase 3 family member A1
32035_at	
41266_at	NM_000210 analysis integrin alpha chain alpha 6
1986_at	NM_005611 analysis retinoblastoma-like 2 p130
32865_at	
38223_at	NM_007063 analysis vascular Rab-GAP/TBC-containing
40934_at	
34056_g_at	NM_004302 analysis activin A type IB receptor precursor NM_020327 analysis activin A type IB receptor isoform b precursor NM_020328 analysis activin A type IB receptor isoform c precursor
1745_at	

31525_s_at	
1484_at	NM_001796 analysis cadherin 8 type 2
36241_r_at	NM_000151 analysis glucose-6-phosphatase catalytic
34120_r_at	
33662_at	
35284_f_at	NM_018199 analysis hypothetical protein FLJ10738
35919_at	NM_001062 analysis transcobalamin I vitamin B12 binding protein R binder family

Table 16 -- CCR/Fail on T(1;19) (continued)

Table 17 -- CCR/Fail on T(9:22)

38299_at	NM_000600 analysis interleukin 6 interferon beta 2
41214_at	NM_001008 analysis ribosomal protein S4 Y-linked
37215_at	
37187_at	NM_002089 analysis GRO2 oncogene
37258_at	NM_003692 analysis transmembrane protein with EGF-like and two follistatin-like domains 1
33734_at	NM_006147 analysis interferon regulatory factor 6
34661_at	
38198_at	
33412_at	
38322_at	NM_007003 analysis JM27 protein
34263_s_at	NM_006729 analysis diaphanous 2 isoform 156 NM_007309 analysis diaphanous 2 isoform 12C
32257_f_at	NM_003218 analysis telomeric repeat binding factor 1 isoform 2 NM_017489 analysis telomeric repeat binding factor 1 isoform 1
34615_at	NM_000223 analysis keratin 12
1147_at	
40757_at	NM_006144 analysis granzyme A precursor
2008_s_at	NM_002392 analysis mouse double minute 2 human homolog of full length protein isoform NM_006878 analysis mouse double minute 2 human homolog of protein isoform MDM2a NM_006879 analysis mouse double minute 2 human homolog of protein isoform MDM2b NM_006880
1304_at	
200_at	
40367_at	NM_001200 analysis bone morphogenetic protein 2 precursor
37441_at	NM_015929 analysis lipoyltransferase
41021_s_at	NM_000408 analysis glycerol-3-phosphate dehydrogenase 2 mitochondrial
1369_s_at	NM_000584 analysis interleukin 8
1113_at	NM_001200 analysis bone morphogenetic protein 2 precursor
802_at	NM_005644 analysis TATA box binding protein TBP associated factor RNA polymerase II J 20kD
35716_at	NM_001056 analysis sulfotransferase family cytosolic 1C member 1
38389_at	NM_002534 analysis 2 5 oligoadenylate synthetase 1 isoform E16 NM_016816 analysis 2 5 oligoadenylate synthetase 1 isoform E18
31862_at	NM_003392 analysis wingless-type MMTV integration site family member 5A
35844_at	NM_002999 analysis syndecan 4 amphiglycan ryudocan
39269_at	NM_002915 analysis replication factor C activator 1 3 38kD
1953_at	NM_003376 analysis vascular endothelial growth factor
34324_at	NM_006493 analysis ceroid-lipofuscinosis neuronal 5
35658_at	NM_000021 analysis presenilin 1 isoform I-467 NM_007318 analysis presenilin 1 isoform I-463 NM_007319

38220_at	analysis presenilin 1 isoform I-374
31359_at	NM_000110 analysis dihydropyrimidine dehydrogenase
658_at	NM_003247 analysis thrombospondin 2
40097_at	NM_004681 analysis eukaryotic translation initiation factor 1A Y chromosome
41548_at	NM_003916 analysis adaptor-related protein complex 1 sigma 2 subunit
38039_at	NM_000103 analysis cytochrome P450 subfamily XIX aromatization of androgens
33538_at	NM_016132 analysis myelin gene expression factor 2
36674_at	NM_002984 analysis small inducible cytokine A4 homologous to mouse Mip-1b

Table 17 -- CCR/Fail on T(9:22) (continued)

Table 18 -- CCR/Fail on T(9:22)

38299_at	NM_000600 analysis interleukin 6 interferon beta 2
41214_at	NM_001008 analysis ribosomal protein S4 Y-linked
37215_at	
37187_at	NM_002089 analysis GRO2 oncogene
37258_at	NM_003692 analysis transmembrane protein with EGF-like and two follistatin-like domains 1
33734_at	NM_006147 analysis interferon regulatory factor 6
34661_at	
38198_at	
33412_at	
38322_at	NM_007003 analysis JM27 protein
34263_s_at	NM_006729 analysis diaphanous 2 isoform 156 NM_007309 analysis diaphanous 2 isoform 12C
32257_f_at	NM_003218 analysis telomeric repeat binding factor 1 isoform 2 NM_017489 analysis telomeric repeat binding factor 1 isoform 1
34615_at	NM_000223 analysis keratin 12
1147_at	
40757_at	NM_006144 analysis granzyme A precursor
2008_s_at	NM_002392 analysis mouse double minute 2 human homolog of full length protein isoform NM_006878 analysis mouse double minute 2 human homolog of protein isoform MDM2a NM_006879 analysis mouse double minute 2 human homolog of protein isoform MDM2b NM_006880
1304_at	
200_at	
40367_at	NM_001200 analysis bone morphogenetic protein 2 precursor
37441_at	NM_015929 analysis lipoyltransferase
41021_s_at	NM_000408 analysis glycerol-3-phosphate dehydrogenase 2 mitochondrial
1369_s_at	NM_000584 analysis interleukin 8
1113_at	NM_001200 analysis bone morphogenetic protein 2 precursor
802_at	NM_005644 analysis TATA box binding protein TBP associated factor RNA polymerase II J 20kD
35716_at	NM_001056 analysis sulfotransferase family cytosolic 1C member 1
38389_at	NM_002534 analysis 2 5 oligoadenylate synthetase 1 isoform E16 NM_016816 analysis 2 5 oligoadenylate synthetase 1 isoform E18
31862_at	NM_003392 analysis wingless-type MMTV integration site family member 5A
35844_at	NM_002999 analysis syndecan 4 amphiglycan ryudocan
39269_at	NM_002915 analysis replication factor C activator 1 3 38kD
1953_at	NM_003376 analysis vascular endothelial growth factor
34324_at	NM_006493 analysis ceroid-lipofuscinosis neuronal 5
35658_at	NM_000021 analysis presentilin 1 isoform I-467 NM_007318 analysis presentilin 1 isoform I-463 NM_007319 analysis presentilin 1 isoform I-374

38220_at	NM_000110	analysis dihydropyrimidine dehydrogenase
31359_at		
658_at	NM_003247	analysis thrombospondin 2
40097_at	NM_004681	analysis eukaryotic translation initiation factor 1A Y chromosome
41548_at	NM_003916	analysis adaptor-related protein complex 1 sigma 2 subunit
38039_at	NM_000103	analysis cytochrome P450 subfamily XIX aromatization of androgens
33538_at	NM_016132	analysis myelin gene expression factor 2
36674_at	NM_002984	analysis small inducible cytokine A4 homologous to mouse Mip-1b

Table 18 -- CCR/Fail on T(9:22) (continued)

Table 19 -- CCR/Fail on Hyperdiploid

38940_at	NM_020675 analysis AD024 protein
39572_at	NM_021956 analysis glutamate receptor ionotropic kainate 2
31616_r_at	
931_at	NM_004951 analysis Epstein-Barr virus induced gene 2 lymphocyte-specific G protein-coupled receptor
40231_at	NM_005585 analysis MAD mothers against decapentaplegic Drosophila homolog 6
40260_g_at	NM_014309 analysis RNA binding motif protein 9
32636_f_at	
37941_at	NM_004533 analysis myosin-binding protein C fast-type
34677_f_at	
157_at	NM_006115 analysis preferentially expressed antigen of melanoma
32985_at	NM_002968 analysis sal Drosophila like 1
37223_at	NM_000232 analysis sarcoglycan beta 43kD dystrophin-associated glycoprotein
40545_at	NM_007198 analysis proline synthetase co-transcribed bacterial homolog
39990_at	NM_002202 analysis islet-1
1758_r_at	NM_000765 analysis cytochrome P450 subfamily IIIA polypeptide 7
38354_at	NM_005194 analysis CCAAT/enhancer binding protein C/EBP beta
38155_at	NM_002553 analysis origin recognition complex subunit 5 yeast homolog like
33585_at	
33815_at	NM_000373 analysis uridine monophosphate synthetase orotate phosphoribosyl transferase and orotidine-5 decarboxylase
38150_at	NM_002451 analysis 5 methylthioadenosine phosphorylase
35472_at	NM_002243 analysis potassium inwardly-rectifying channel subfamily J member 15
764_s_at	
31468_f_at	
39780_at	NM_021132 analysis protein phosphatase 3 formerly 2B catalytic subunit beta isoform calcineurin A beta
2044_s_at	NM_000321 analysis retinoblastoma 1 including osteosarcoma
38652_at	NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
537_f_at	NM_012165 analysis f-box and WD-40 domain protein 3
41145_at	NM_014883 analysis KIAA0914 gene product
35669_at	
33462_at	NM_014879 analysis KIAA0001 gene product putative G-protein-coupled receptor G protein coupled receptor for UDP-glucose
1375_s_at	NM_003255 analysis tissue inhibitor of metalloproteinase 2 precursor
40326_at	NM_004352 analysis cerebellin 1 precursor
32368_at	NM_002590 analysis protocadherin 8

35014_at	
38772_at	NM_001554 analysis cysteine-rich angiogenic inducer 61
32434_at	NM_002356 analysis myristoylated alanine-rich protein kinase C substrate
1609_g_at	
1648_at	NM_003999 analysis oncostatin M receptor
35173_at	
36693_at	NM_001990 analysis eyes absent Drosophila homolog 3

Table 19 -- CCR/Fail on Hyperdiploid (continued)

EXAMPLE VI.

Application of ANOVA to VxInsight Clusters to Identify Genes Associated with Outcome

5 To identify genes strongly predictive of outcome in pediatric ALL, we divided the retrospective POG ALL case control cohort (n=254) described above into training (2/3 of cases) and test (1/3 of cases) sets performed statistical analyses using VxInsight and ANOVA. Through this approach, we identified a limited set of novel genes that were predictive of outcome in
10 pediatric ALL. Table 20 provides the list of the top 20 genes associated with remission vs. failure in the pre-B ALL cohort; several of these genes appear to reach statistical significance. These top 20 genes are ranked by ANOVA f statistics; we have also converted these f statistics to corresponding p values. Not surprisingly, overall p values for outcome prediction in VxInsight or with
15 any other method are less than for prediction of genetic types or morphologic labels; we assume that this is due to the significant biologic heterogeneity of the outcome variable in our patient cohorts. A positive value in the "Contrast" column of Table 20 reveals that the gene identified is expressed at relatively higher levels in patients in long term remission; a negative value indicates that a
20 particular gene is expressed at lower levels in patients in remission and at higher levels in patients who fail therapy.

Table 20: Genes Statistically Distinguishing R mission vs. Fail: VxInsight

Order	ANOVA_F	nsiORF	Contrast	p	Description
1	26.58	39418_at	<u>-2279.06</u>	p<=0.024	DKFZP564M182 protein
2	18.95	37981_at	<u>2461.77</u>	p<=0.046	drebrin 1
3	18.87	38971_r_at	<u>-1874.42</u>	p<=0.057	Nef-associated factor 1
4	18.82	38119_at	<u>-2515.9</u>	p<=0.074	glycophorin C isoform 2
5	17.18	671_at	<u>-1340.48</u>	p<=0.068	secreted protein acidic cysteine-rich osteonectin
6	16.74	577_at	<u>3653.53</u>	p<=0.125	midkine neurite growth-promoting factor 2
7	16.05	37343_at	<u>3009.04</u>	p<=0.122	inositol 1 4 5-triphosphate receptor type 3
8	14.37	1126_s_at	<u>-2870.22</u>	p<=0.177	Human cell surface glycoprotein CD 44 gene, 3' end of long tailed isoform
9	14.33	32970_f_at	<u>1440.29</u>	p<=0.127	hyaluronan binding protein
10	13.83	41185_f_at	<u>1446.05</u>	p<=0.190	SMT3 suppressor of mif two 3 yeast homolog 2
11	13.78	33362_at	<u>-1537.08</u>	p<=0.175	Cdc42 effector protein 3
12	13.74	38652_at	<u>1811.99</u>	p<=0.029	NM_017787 hypothetical protein FLJ20154 NM_017787 hypothetical protein FLJ20154
13	13.31	824_at	<u>-2173.7</u>	p<=0.160	glutathione-S-transferase like

Order	ANOVA_F	nsiORF	Contrast	p	Description
14	13.28	35796_at	<u>-1815.29</u>	p<=0.243	protein tyrosine kinase 9-like A6-related protein
15	13.06	40523_at	<u>1523.7</u>	p<=0.178	hepatocyte nuclear factor 3 beta
16	13.06	37184_at	<u>-2181.49</u>	p<=0.151	syntaxin 1A brain
17	13.04	34890_at	<u>-1087.46</u>	p<=0.195	ATPase H transporting lysosomal vacuolar proton pump alpha polypeptide 70kD isoform 1
18	12.94	41257_at	<u>-1030.55</u>	p<=0.155	calpastatin
19	12.86	41819_at	<u>1020.59</u>	p<=0.264	FYN-binding protein FYB-120/130
20	12.71	32058_at	<u>1413.3</u>	p<=0.214	HNK-1 sulfotransferase

Interestingly, OPAL1/G0 (38652_at; NM_Hypothetical protein FLJ20154); see Example II), at position 12 on the table, appeared on gene lists produced by four different supervised learning algorithms (Bayesian networks, SVM, Neurofuzzy logic) and was ranked extremely high (top 5 or 10 genes) or at the top (Bayesian) with each of these very distinct modeling approaches. The degree of overlap between outcome genes detected with these different modeling algorithms was quite striking.

The gene at the number 5 position on the table (Affy number 671_at, known as SPARC, secreted protein, acidic, cysteine-rich (osteonectin)) is interesting as a possible therapeutic target. Osteonectin is involved in development, remodeling, cell turnover and tissue repair. Because its principal functions *in vitro* seem to be involved in counteradhesion and antiproliferation (Yan et al., J. Histochem. Cytochemi. 47(12):1495-1505, 1999). These characteristics may be consistent with certain mechanisms of metastasis. Further, it appears to have a role in cell cycle regulation, which, again, may be

important in cancer mechanisms. Furthermore, it should be noted that other significant (about $p < 0.10$) genes on the list might also have mechanisms that, together, could be combined to suggest mechanisms consistent with the observed differences in CCR and FAILURE. The group of genes, or subsets of it, may have more explanatory power than any individual member alone.

EXAMPLE VII

Genes That Distinguish Karyotype Identified by Bayesian Methods

In the context of disease karyotype subtype prediction, we applied Bayesian nets to the preB training set data in a supervised learning environment. A set of training data, labeled with disease karyotype subtype, is used to generate and evaluate hypotheses against the test data. The Bayesian net approach filters the space of all genes down to K (typically, K between 20 and 50) genes selected by one of several evaluation criteria based on the genes' potential information content. For each classification task attempted, a cross validation methodology is employed to determine for what value of K , and for which of the candidate evaluation criteria, the best Bayesian net classification accuracy is observed in cross validation. Surviving hypotheses are blended in the Bayesian framework, yielding conditional outcome distributions. Hypotheses so learned are validated against an out-of-sample test set in order to assess generalization accuracy.

Approximately 30 genes from prediction of each karyotype were combined. The gene list in Table 21 can discriminate translocations of $t(12;21)$, $t(1;19)$, $t(4;11)$, $t(9;22)$ as well as hyperdiploid and hypodiploid karyotype from normal karyotype.

Table 21. Genes for karyotype distinction derived from Bayesian Analysis of pediatric ALL microarray samples

<u>Affymetrix ID</u>	<u>Gene description</u>
35362_at	hg01449 cDNA clone for KIAA0799 has a 1204-bp insertion at position 373 of the sequence of KIAA0799.
1325_at	Sma and Mad homolog
1077_at	recombination activating protein

	34194_at	Source: Homo sapiens mRNA; cDNA DKFZp564B076 (from clone DKFZp564B076).
	32730_at	Source: Homo sapiens mRNA; cDNA DKFZp564H142 (from clone DKFZp564H142).
5	34745_at	Source: Homo sapiens clone 24473 mRNA sequence.
	37986_at	Source: Human erythropoietin receptor mRNA, complete cds.
	40570_at	Source: Homo sapiens forkhead protein (FKHR) mRNA, complete cds.
	40272_at	Source: Homo sapiens mRNA for dihydropyrimidinase related protein-1, complete cds.
10	2036_s_at	Source: Human cell adhesion molecule (CD44) mRNA, complete cds.
	35940_at	Source: H.sapiens mRNA for RDC-1 POU domain containing protein.
	41097_at	telomeric protein
	39931_at	dual specificity protein kinase
	31472_s_at	hyaluronan-binding protein; soluble isoform CD44RC; alternatively
15	spliced	
	32227_at	hematopoietic proteoglycan core protein (AA 1 - 158)
	37280_at	Mad homolog
	36524_at	hj05505 cDNA clone for KIAA1112 has 983-bp and 352-bp insertions at the positions 820 and 1408 of the sequence of KIAA1112.
20	39824_at	Source: tg16b02.x1 NCI_CGAP_CLL1 Homo sapiens cDNA clone IMAGE:2108907 3', mRNA sequence.
	35260_at	Source: Homo sapiens mRNA for KIAA0867 protein, complete cds.
	35614_at	Source: Homo sapiens TCFL5 mRNA for transcription factor-like 5, complete cds.
25	37497_at	orphan homeobox gene
	41814_at	alpha-L-fucosidase precursor (EC 3.2.1.5)
	1980_s_at	Source: H.sapiens RNA for nm23-H2 gene.
	36008_at	potentially prenylated protein tyrosine phosphatase
	36638_at	Source: H.sapiens mRNA for connective tissue growth factor.
30	40367_at	bone morphogenetic protein 2A
	32163_f_at	Source: zq95f07.s1 Stratagene NT2 neuronal precursor 937230 Homo sapiens cDNA clone IMAGE:649765 3' similar to contains LTR7.b3 LTR7 repetitive element ;, mRNA sequence.
35	755_at	Source: Human mRNA for type 1 inositol 1,4,5-trisphosphate receptor, complete cds.
	32724_at	Refsum disease gene
	39327_at	similar to D.melanogaster peroxidase(U11052)
	39717_g_at	Source: tn15f08.x1 NCI_CGAP_Brn25 Homo sapiens cDNA clone IMAGE:2167719 3', mRNA sequence.
40	33412_at	Source: vicpro2.D07.r conorm Homo sapiens cDNA 5', mRNA
	sequence.	
	40763_at	TALE homeobox protein
	31575_f_at	beta-galactoside-binding lectin
	1039_s_at	basic helix-loop-helix transcription factor
45	36873_at	Source: Human gene for very low density lipoprotein receptor, exon 19.
	1914_at	Source: Human cyclin A1 mRNA, complete cds.
	32529_at	Source: H.sapiens p63 mRNA for transmembrane protein.
	32977_at	Source: Human placenta (Diff48) mRNA, complete cds.
50	37724_at	c-myc oncogene
	39338_at	Source: qf71b11.x1 Soares_testis_NHT Homo sapiens cDNA clone IMAGE:1755453 3' similar to gb:M38591 CALPACTIN I LIGHT CHAIN (HUMAN);, mRNA sequence.
	1973_s_at	c-myc oncogene
55	31444_s_at	Source: Human lipocortin (LIP) 2 pseudogene mRNA, complete cds-like region.
	36897_at	Source: Homo sapiens mRNA for KIAA0027 protein, partial cds.
	34210_at	Source: zb11b10.s1 Soares_fetal_lung_NbHL19W Homo sapiens cDNA clone IMAGE:301723 3' similar to gb:X62466 H.sapiens mRNA for CAMPATH-1 (HUMAN);, mRNA sequence.
60		

	266_s_at	Source: Homo sapiens CD24 signal transducer mRNA, complete cds and 3' region.
	769_s_at	Source: Homo sapiens mRNA for lipocortin II, complete cds.
	36536_at	Source: Homo sapiens clone 24732 unknown mRNA, partial cds.
5	38413_at	Source: Human mRNA for DAD-1, complete cds.
	41170_at	Source: Homo sapiens mRNA for KIAA0663 protein, complete cds.
	37680_at	kinase scaffold protein
	38518_at	Source: Homo sapiens mRNA for SCML2 protein.
	36514_at	Source: Human cell growth regulator CGR19 mRNA, complete cds.
10	40396_at	ionotropic ATP receptor
	40417_at	KIAA0098 is a human counterpart of mouse chaperonin containing TCP-1 gene. Start codon is not identified. ha01413 cDNA clone for KIAA0098 has a 2-bp insertion between 736-737 of the sequence of KIAA0098.
15	486_at	prodomain of this protease is similar to the CED-3 prodomain; proMch6 is a new member of the aspartate-specific cysteine protease family
	32232_at	Source: Homo sapiens NADH-ubiquinone oxidoreductase subunit CI-SGDH mRNA, complete cds.
20	33355_at	Source: Homo sapiens mRNA; cDNA DKFZp586J2118 (from clone DKFZp586J2118).
	36203_at	Source: Human gene for ornithine decarboxylase ODC (EC 4.1.1.17).
	37306_at	ha1025 is new
	1081_at	ornithine decarboxylase
25	40454_at	Source: H.sapiens mRNA for hFat protein.
	1616_at	Source: Human mRNA for FGF-9, complete cds.
	36452_at	Source: Homo sapiens mRNA for KIAA1029 protein, complete cds.
	35727_at	Source: qj64d06.x1 NCI_CGAP_Kid3 Homo sapiens cDNA clone IMAGE:1864235 3' similar to WP:F19B6.1 CE05666 URIDINE KINASE ;, mRNA sequence.
30	753_at	Source: Homo sapiens mRNA for osteonidogen, complete cds.
	32063_at	Source: H.sapiens PBX1a and PBX1b mRNA, complete cds.
	1797_at	CDK inhibitor p19
	362_at	Source: H.sapiens mRNA for protein kinase C zeta.
35	39829_at	Source: Homo sapiens mRNA for ADP ribosylation factor-like protein, complete cds.
	717_at	Source: Homo sapiens mRNA for GS3955, complete cds.
	854_at	protein tyrosine kinase
	38285_at	Source: Homo sapiens mu-crystallin gene, exon 8 and complete cds.
40	41138_at	Source: Human MIC2 mRNA, complete cds.
	40113_at	Source: Homo sapiens mRNA for GS3955, complete cds.
	36069_at	Source: Homo sapiens mRNA for KIAA0456 protein, partial cds.
	37579_at	inducible protein
	37225_at	similar to ankyrin of Chromatium vinosum.
45	39614_at	hh01783 cDNA clone for KIAA0802 has a 152-bp insertion at position 2490 of the sequence of KIAA0802.
	38748_at	alternatively spliced
	33513_at	Source: Human signaling lymphocytic activation molecule (SLAM) mRNA, complete cds.
50	39729_at	Source: Human natural killer cell enhancing factor (NKEFB) mRNA, complete cds.
	37493_at	Source: yj49e08.r1 Soares placenta Nb2HP Homo sapiens cDNA clone IMAGE:152102 5', mRNA sequence.
	1788_s_at	MAP kinase phosphatase
55	39929_at	Source: Homo sapiens mRNA for KIAA0922 protein, partial cds.
	37701_at	also called RGS2
	34335_at	Source: wi81c01.x1 NCI_CGAP_Kid12 Homo sapiens cDNA clone IMAGE:2399712 3', mRNA sequence.
60	1636_g_at	ABL is the cellular homolog proto-oncogene of Abelson's murine leukemia virus and is associated with the t9:22 chromosomal

		translocation with the BCR gene in chronic myelogenous and acute lymphoblastic leukemia; alternative splicing using exon 1a
	39730_at	p150 protein (AA 1-1130)
5	37006_at	Source: wf23c07.x1 Soares_Dieckgraefe_colon_NHUC Homo sapiens cDNA clone IMAGE:2351436 3', mRNA sequence.
	33131_at	Source: H.sapiens mRNA for SOX-4 protein.
	36031_at	Source: Homo sapiens mRNA for p33, complete cds.
	38968_at	This protein preferentially associates with activated form of Btk(Sab).
10	40202_at	three-times repeated zinc finger motif
	38119_at	Source: Human mRNA for erythrocyte membrane sialoglycoprotein beta (glycophorin C).
	36601_at	vinculin
	32260_at	Source: H.sapiens mRNA for major astrocytic phosphoprotein PEA-15.
	34550_at	Source: Human mRNA for D-1 dopamine receptor.
15	37399_at	Source: Human mRNA for KIAA0119 gene, complete cds.
	38994_at	similar to product encoded by GenBank Accession Number AB004903
	1583_at	Source: Human tumor necrosis factor receptor mRNA, complete cds.
	1461_at	Source: Homo sapiens MAD-3 mRNA encoding Ikb-like activity, complete cds.
20	33885_at	Source: Homo sapiens mRNA for KIAA0907 protein, complete cds.
	34889_at	Source: zk81f02.s1 Soares_pregnant_uterus_NbHPU Homo sapiens cDNA clone IMAGE:489243 3', mRNA sequence.
	40790_at	basic helix-loop-helix protein
	38276_at	Source: Human I kappa B epsilon (IkbE) mRNA, complete cds.
25	36543_at	tissue factor versions 1 and 2 precursor
	36591_at	Source: Human HALPHA44 gene for alpha-tubulin, exons 1-3.
	37600_at	Source: Human extracellular matrix protein 1 mRNA, complete cds.
	1295_at	675_at interferon-inducible protein 9-27
30	37732_at	putative
	669_s_at	Source: Homo sapiens mRNA; cDNA DKFZp564E1922 (from clone DKFZp564E1922).
	38313_at	Source: Homo sapiens interferon regulatory factor 1 gene, complete cds.
35	35256_at	Source: Homo sapiens mRNA for KIAA1062 protein, partial cds.
	35688_g_at	Source: Homo sapiens mRNA; cDNA DKFZp434F152 (from clone DKFZp434F152).
	32139_at	Source: H.sapiens MTCP1 gene, exons 2A to 7 (and joined mRNA).
	40296_at	Source: H.sapiens mRNA for ZNF185 gene.
40	149_at	match: proteins O43895 Q95333 Q07825 O15250 O54975
		DEAD-box family member; contains DECD-box; similar to rat liver nuclear protein p47 (PIR Accession Number A42881) and D. melanogaster DEAD-box RNA helicase WM6 (PIR Accession Number S51601)
45	32251_at	Source: zl25h05.s1 Soares_pregnant_uterus_NbHPU Homo sapiens cDNA clone IMAGE:503001 3', mRNA sequence.
	37014_at	p78 protein
	1272_at	Source: Human translation initiation factor eIF-2 gamma subunit mRNA, complete cds.
50	40771_at	match: proteins Sw:P26038 Tr:O35763 Sw:P26041 Sw:P26042 Sw:P26044 Sw:P35241 Sw:P26043 Sw:P15311 Sw:P31976 Sw:P26040 Tr:Q26520 Tr:Q24788 Tr:Q24796 Tr:Q94815
	32941_at	Source: Homo sapiens DNA-binding protein mRNA, complete cds.
	37001_at	Ca2-activated
55	37421_f_at	Source: Human DNA sequence from clone RP3-377H14 on chromosome 6p21.32-22.1, complete sequence.
	39755_at	match: proteins Sw:P17861 Tr:O35426
	33936_at	Source: Homo sapiens DNA for galactocerebrosidase, exon 17 and complete cds.
	40370_f_at	Source: Human lymphocyte antigen (HLA-G1) mRNA, complete cds.

	32788_at	This giant protein comprises an amino-terminal 700-residue leucine-rich region, four RanBP1-homologous domains, eight zinc-finger motifs similar to those of NUP153 and a carboxy terminus with high homology to cyclophilin.
5	34990_at	isolated by yeast two-hybrid screening
	36927_at	The submitters designated this product as GS3686
	2031_s_at	Source: Human wild-type p53 activated fragment-1 (WAF1) mRNA, complete cds.
	40518_at	precursor polypeptide (AA -23 to 1120)
10	38336_at	hj06791 cDNA clone for KIAA1013 has a 4-bp deletion at position between 1855 and 1860 of the sequence of KIAA1013.
	39059_at	D7SR
	547_s_at	NGFI-B/nur77 beta-type transcription factor homolog
	36048_at	Source: Homo sapiens HRIHFB2436 mRNA, partial cds.
15	33061_at	Source: Homo sapiens C16orf3 large protein mRNA, complete cds.
	40712_at	CD156; ADAM8; MS2
	39290_f_at	Source: 44c1 Human retina cDNA randomly primed sublibrary Homo sapiens cDNA, mRNA sequence.
	35408_i_at	Source: Human mRNA for zinc finger protein (clone 431).
20	36103_at	Source: Homo sapiens gene for LD78 alpha precursor, complete cds.

Example VIII.

Discriminant Analysis of Pre-B ALL Cohort Data to Discriminate Between
25 Remission and Failure and Among Various Karyotypes

Classification tasks and the class labels

We used supervised learning methods to discriminate between positive
and negative outcomes (Remission (CCR) vs. Failure) and to discriminate
30 among various karyotypes. The outcome statistics for the 167 member "training
set" derived from the 254 member pre-B ALL cohort are shown in Table 22.

Table 22. Class Labels for Outcome Prediction

Label	Class Name	# of Samples in the Class
1	CCR	73
2	Failure	94

35

To discriminate among the various karyotypes, we considered three different classifications of the karyotypes (Table 23).

Table 23. Class Labels for Karyotype Discrimination

No.	Karyotype	Class Labels	# of Samples in the Class
1	T(12; 21)	1	24
2	T(4; 11)	2	14
3	T(1; 19)	3	21
4	T(9; 22)	4	10
5	Hyperdiploid	5	17
6	Hypodiploid	4	2
7	Normal	6	65
8	Unknown	7	14

5

Data preprocessing

The analysis was performed on the data set comprising the 167 training cases. We first eliminated the 54 of 67 control genes (those with accession ID starting with the AFFX prefix), and then eliminated those genes with all calls "Absent" for all 167 training cases. With these genes removed from the original 12625, we were left with 8582 genes. In addition, a natural log transformation was performed on 8582×167 matrix of the gene expression values prior to further analysis.

15

Ranking genes

The 8582 genes are ranked by two methods based on ANOVA for each classification exercise. Method 1 ranks the genes in terms of the F-test statistic values. Method 2 assigns a rank to each gene in terms of the number of pairs of classes between which the gene's expression value differs significantly. Note that for binary classification problem (remission vs. failure), only Method 1 is applicable.

20

Discriminating among the classes

An optimal subset of prediction genes is further selected from top 200 genes of a given ranked gene list through the use of stepwise discriminant analysis. Then the classes are discriminated using the linear discriminant analysis. The classification error rate is estimated through the leave-one-out cross validation (LOOCV) procedure. A visualization of the class separation for each classification is produced with canonical discriminant analysis.

Discrimination between Remission and Failure

The one way ANOVA (F -test, which is equivalent to two-sample t -test in this case) was performed for each of 8582 pre-selected genes and then the all these genes were ranked in terms of the p -value of F -test. The numbers of 0.05 and 0.01 significant discriminating genes are 493 and 108, respectively. The top 20 significant discriminating genes are tabulated in Table 24. An optimal subset of discriminating genes were selected from the top 200 genes using the stepwise discriminant analysis was also prepared. The number one significant prediction gene in both the ranked gene list and the optimal subset of prediction genes is 38652_at, hypothetical protein FLJ20154, corresponding to OPAL1/G0.

The optimal subset of discriminating genes was utilized with linear discriminant analysis to predict for Remission (CCR) vs. failure in the training set of 167 cases. The success rate of the predictor is estimated in three ways: Resubstitution, LOOCV with Fold Independent prediction genes, LOOCV with Fold dependent prediction genes, and the results are listed in Table 25.

Table 24. Top significant discriminating genes for Remission vs. Failure

Rank	Stepwise	F	p-value	Probe Set	Probe Set Description
1	1	22.8448	0.00000	38652_at	hypothetical protein FLJ20154
2	1	16.1718	0.00009	38119_at	glycophorin C (Gerbich blood group)
3	0	14.9168	0.00016	39418_at	DKFZP564M182 protein
4	0	14.5669	0.00019	671_at	secreted protein, acidic, cysteine-rich (osteonectin)
5	0	13.8615	0.00027	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041
6	0	13.1511	0.00038	35796_at	protein tyrosine kinase 9-like (A6-related protein)
7	0	12.8494	0.00044	38270_at	poly (ADP-ribose) glycohydrolase
8	0	12.6702	0.00049	587_at	endothelial differentiation, sphingolipid G-protein-coupled receptor, 1
9	0	12.1639	0.00062	38971_r_at	Nef-associated factor 1
10	0	11.6172	0.00082	34760_at	KIAA0022 gene product
11	0	11.3141	0.00096	31527_at	ribosomal protein S2
12	0	11.2706	0.00098	37674_at	Aminolevulinate, delta-, synthase 1
13	0	10.5358	0.00142	36144_at	KIAA0080 protein
14	1	10.3798	0.00154	36154_at	KIAA0263 gene product
15	0	10.3236	0.00158	1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
16	1	10.3063	0.00159	31695_g_at	regulatory solute carrier protein, family 1, member 1
17	0	10.1814	0.00170	36927_at	hypothetical protein, expressed in osteoblast
18	0	10.1600	0.00172	34965_at	cystatin F (leukocystatin)
19	0	10.1129	0.00176	32336_at	aldolase A, fructose-bisphosphate
20	0	10.0426	0.00182	625_at	membrane protein of cholinergic synaptic vesicles

Note: stepwise=1 means that the gene belongs to the optimal subset of prediction genes.

Table 25. Estimate for Prediction Success Rate

Method	# of Misclassifications	Overall Success Rate
Resubstitution	3	0.9820
LOOCV with fold independent prediction genes	8	0.9521
LOOCV with fold dependent prediction genes	43	0.7425

Discrimination among various karyotypes

The one way ANOVA (F -test) and the pair-wise comparison t -test were performed for each of 8582 pre-selected genes for the karyotype classification problem. Next, all genes were ranked based on the two methods described for
5 outcome discrimination. The top 20 genes in each of ranked gene lists are listed in Tables 26 and 27. The tables also list the values of the statistic F and the number of pairs of classes between which the gene expression value differs at confidence level $\alpha=0.10$, which is labeled as SIG#. An optimal subset of discriminating genes for each of the classes was selected from the top 200 genes
10 with the stepwise discriminant analysis.

Each optimal subset of discriminating genes was utilized with linear discriminant analysis to predict for the corresponding classes in the training set of 167 cases. The success rate of the predictor is estimated in the same way as described in above for outcome prediction and the results are listed in Table 28.

Table 26. Top significant discriminating genes for karyotype.

Genes selected by Method 1

Rank	Step-wise	F	p-value	Sig #	Probe Set	Probe Set Description
1	1	25.8207	0.00000	8	33355_at	Homo sapiens mRNA; cDNA DKFZp586J2118 (from clone DKFZp586J2118)
2	1	22.6173	0.00000	6	36452_at	synaptopodin
3	1	20.7497	0.00000	11	40272_at	collapsin response mediator protein 1
4	1	20.5471	0.00000	13	34335_at	ephrin-B2
5	0	20.1257	0.00000	9	32063_at	pre-B-cell leukemia transcription factor 1
6	0	18.1686	0.00000	10	38285_at	crystallin, mu
7	0	17.4124	0.00000	14	1325_at	MAD (mothers against decapentaplegic, Drosophila) homolog 1
8	0	16.4965	0.00000	9	41097_at	telomeric repeat binding factor 2
9	0	16.1843	0.00000	15	37280_at	MAD (mothers against decapentaplegic, Drosophila) homolog 1
10	0	15.8108	0.00000	6	35362_at	myosin X
11	1	15.7074	0.00000	15	33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
12	0	15.4828	0.00000	14	35940_at	POU domain, class 4, transcription factor 1
13	1	15.0498	0.00000	11	1081_at	ornithine decarboxylase 1
14	0	14.3251	0.00000	12	717_at	GS3955 protein
15	1	14.2303	0.00000	16	40570_at	forkhead box O1A (rhabdomyosarcoma)
16	0	14.0783	0.00000	14	32977_at	chromosome 6 open reading frame 32
17	0	14.0752	0.00000	15	37680_at	A kinase (PRKA) anchor protein (gravin) 12
18	0	13.9742	0.00000	12	854_at	B lymphoid tyrosine kinase
19	0	13.8677	0.00000	6	1077_at	recombination activating gene 1
20	0	13.7766	0.00000	17	37343_at	inositol 1,4,5-triphosphate receptor, type 3

Table 27. Top significant discriminating genes karyotype

Genes selected by Method 2

Rank	Step-wise	F	p-value	Sig #	Probe Set	Probe Set Description
1	0	13.7766	0.00000	17	37343_at	inositol 1,4,5-triphosphate receptor, type 3
2	0	13.4313	0.00000	17	182_at	inositol 1,4,5-triphosphate receptor, type 3
3	1	13.0765	0.00000	17	37539_at	RaIGDS-like gene
4	0	14.2303	0.00000	16	40570_at	forkhead box O1A (rhabdomyosarcoma)
5	1	13.0270	0.00000	16	307_at	arachidonate 5-lipoxygenase
6	0	12.9726	0.00000	16	38340_at	huntingtin interacting protein-1-related
7	0	12.7724	0.00000	16	32827_at	related RAS viral (r-ras) oncogene homolog 2
8	0	11.6961	0.00000	16	36536_at	schwannomin-interacting protein 1
9	0	11.4521	0.00000	16	32554_s_at	transducin (beta)-like 1
10	0	10.1963	0.00000	16	36650_at	cyclin D2
11	0	10.1845	0.00000	16	38968_at	SH3-domain binding protein 5 (BTK-associated)
12	0	10.0070	0.00000	16	38518_at	sex comb on midleg (Drosophila)-like 2
13	0	8.6339	0.00000	16	37981_at	drebrin 1
14	0	7.6949	0.00000	16	35794_at	KIAA0942 protein
15	0	16.1843	0.00000	15	37280_at	MAD (mothers against decapentaplegic, Drosophila) homolog 1
16	1	15.7074	0.00000	15	33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
17	0	14.0752	0.00000	15	37680_at	A kinase (PRKA) anchor protein (gravin) 12
18	0	12.8180	0.00000	15	675_at	interferon induced transmembrane protein 1 (9-27)
19	0	11.9668	0.00000	15	39929_at	KIAA0922 protein
20	1	11.4160	0.00000	15	38748_at	adenosine deaminase, RNA-specific, B1 (homolog of rat RED1)

Table 28. Estimates of Prediction Success Rates for Karyotype Discrimination

Task	Estimation method	Number of mis-classifications	Overall Success Rate
Gene selection method 1	Resubstitution	9	0.9461
	FIPG LOOCV	28	0.8323
	FDPG LOOCV	58	0.6527
Gene selection method 2	Resubstitution	10	0.9401
	FIPG LOOCV	30	0.8204
	FDPG LOOCV	55	0.6707

Example IX.

Uniformly Significant Genes that Are Correlated with CCR vs. Failure

5

The three data sets derived from the retrospective statistically designed 254 member Pre-B data set were analyzed for their association with outcome: the 167 member training set, the 87 member test set and overall 254 member data set. Three measures were used: ROC accuracy A, F-test statistic and TNoM . Table 29 shows a list of genes correlated with outcome with the ranks determined by these different measures with the different data sets.

10

Two genes were consistently significant in both training and test sets and they are number one and number two significant genes in the overall data set. The two genes are 39418_at, DKFZP564M182 protein (PBK1) and 41819_at, FYN-binding protein (FYB-120/130). FYN is a tyrosine kinast found in fibroblasts and T lymphocytes (Popescu et al., Oncogene 1(4):449-451 (1987)).

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Unexpectedly, although OPAL1/G0 was the most significant gene in the training data set, it was a much less significant gene in the test data set. Indeed, most of the significant genes in training set, like OPAL1/G0, became less significant in test set. The fact that most genes that did well in the training set did poorly in the test set lends support to our hypothesis that the test set's composition differed significantly from that of the training set. We therefore sought to increase the robustness of this statistical analysis.

20

Re-sampling training and test data sets

Our goal was to identify genes that are significant irrespective of the data set. One way to get a stable (robust) list of genes that are highly correlated with the distinction of CCR vs. Failure is through the use of a random re-sampling (bootstrap) procedure. We randomly divided the overall data set into training and test sets 172 times. The numbers of CCRs and Failures in the training set was fixed to agree with the original training set, (i.e. 73 CCR s and 94 Failures). Each time the genes are ranked in the same way as in Table 1. That is, we produced 172 tables like Table 29 for the 172 different training and test sets.

We found that the gene ranking in the two data sets (training and test randomly resampled in each time) are typically quite different. However, in most runs, the two genes 39418_at (PBK1) and 41819_at (FYN-binding protein) were consistently significant in both the random training and test sets. We called these two genes the uniformly most significant genes. OPAL1/G0 (38652_at) also consistently shows significance.

Generation of a robust gene list (a list of uniformly significant genes)

The following rule was used to assign a quantitative value to each gene to evaluate the extent that the gene is uniformly significant: in each training and test set, the genes are ranked by three measures. After 172 resamplings, each gene has 172 ranks on the three measures in each of two data sets. We calculate the average or mean of the 172 ranks of each gene. We then sorted the genes on the mean ranks. In this way we get a robust gene list corresponding to each of three measures in each of the two data sets.

The top 100 genes in the robust gene list are presented in Table 30 with the robust ranks determined by the three different measures. We found that the ranks in training set and test set closely agree with each other and with the rank determined by the overall data set. The two most uniformly significant genes (39418_at and 41819_at) were ranked first and second. OPAL1/G0 survives in this analysis and had good average ranks on the three measures, but was only about 10th best overall.

Table 29. Ranks of significant Genes Generated in Original Training, Test and Overall Data Sets

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
1	1	1	7695	7493	7251	10	7	6	38652_at	hypothetical protein FLJ20154
2	2	54	60	122	94	1	1	7	39418_at	DKFZP564M182 protein
3	5	22	3757	3530	4708	14	17	32	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041
4	14	32	8337	8425	1894	132	253	266	37674_at	aminolevulinate, delta-, synthase 1
5	6	10	4353	4210	5827	31	23	83	38270_at	poly (ADP-ribose) glycohydrolase
6	3	49	2354	818	2966	12	2	81	38119_at	glycophorin C (Gerbich blood group)
7	4	35	1026	945	2202	6	3	65	671_at	secreted protein, acidic, cysteine-rich (osteonectin)
8	20	12	1702	933	1418	8	12	66	1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
9	7	38	3684	7525	5011	25	78	143	31527_at	ribosomal protein S2
10	9	61	7679	6989	7628	150	166	286	587_at	endothelial differentiation, sphingolipid G-protein-coupled receptor, 1
11	26	45	3263	4366	6960	30	86	168	36144_at	KIAA0080 protein
12	22	63	6526	6224	7633	97	125	204	625_at	membrane protein of cholinergic synaptic vesicles
13	10	212	6098	6724	5394	75	93	335	34760_at	KIAA0022 gene product
14	18	143	2541	1713	7043	20	21	359	36927_at	hypothetical protein, expressed in osteoblast
15	8	17	5147	5142	7971	72	34	162	35796_at	protein tyrosine kinase 9-like (A6-related protein)
16	35	14	7445	8457	7792	175	205	460	32336_at	aldolase A, fructose-bisphosphate

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
17	161	74	6925	5891	6648	138	374	318	33188_at	peptidylprolyl isomerase (cyclophilin)-like 2
18	109	11	38	63	104	2	8	2	41819_at	FYN-binding protein (FYB-120/130)
19	56	36	3000	4192	4982	45	161	139	2062_at	insulin-like growth factor binding protein 7
20	43	124	6998	5801	6770	333	514	1373	34349_at	SEC63 protein
21	25	184	7476	7310	8582	168	175	1219	932_i_at	zinc finger protein 91 (HPF7, HTF10)
22	198	149	2380	3049	2927	36	238	80	37748_at	KIAA0232 gene product
23	12	83	3966	8153	4329	115	231	175	38440_s_at	hypothetical protein
24	33	96	6080	6141	6364	144	119	856	106_at	runt-related transcription factor 3
25	54	20	80	90	177	4	6	3	37343_at	inositol 1,4,5-triphosphate receptor, type 3
26	59	199	3436	3294	6609	78	123	316	32703_at	serine/threonine kinase 18
27	31	18	1805	2464	4031	35	36	121	36154_at	KIAA0263 gene product
28	50	48	1479	1275	1931	1520	2214	3445	38111_at	chondroitin sulfate proteoglycan 2 (versican)
29	36	5	4225	4623	4966	68	111	19	1980_s_at	non-metastatic cells 2, protein (NM23B) expressed in
30	21	214	4722	4614	6831	87	58	693	34965_at	cystatin F (leukocystatin)
31	39	118	410	385	297	9	10	11	33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
32	48	159	4699	3446	7359	667	1045	2761	39607_at	myotubularin related protein 8
33	87	677	4246	4880	4929	908	1194	4856	1698_g_at	mitogen-activated protein kinase kinase 5
34	41	42	7549	7856	7947	195	212	119	35322_at	Kelch-like ECH-associated protein 1
35	200	75	2290	4897	5290	53	484	155	33866_at	tropomyosin 4
36	23	728	1700	2677	1584	37	54	149	32623_at	gamma-aminobutyric acid (GABA) B receptor, 1

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
37	38	348	2662	3937	4001	57	67	1022	35939_s_at	POU domain, class 4, transcription factor 1
38	24	132	6369	8517	6890	629	371	346	35614_at	transcription factor-like 5 (basic helix-loop-helix)
39	15	422	3450	2407	4730	91	25	417	41656_at	N-myristoyltransferase 2
40	82	299	5587	5878	5033	215	354	454	31830_s_at	smoothelin
41	28	297	4620	2982	5023	140	51	892	31695_g_at	regulatory solute carrier protein, family 1, member 1
42	27	210	2295	3602	1699	67	68	112	34433_at	docking protein 1, 62kD (downstream of tyrosine kinase 1)
43	67	432	656	367	3375	16	13	205	824_at	glutathione-S-transferase like; glutathione transferase omega
44	53	631	5724	6981	6154	712	587	2164	40817_at	nucleobindin 1
45	37	87	3277	3624	6098	88	81	400	40365_at	guanine nucleotide binding protein (G protein), alpha 15 (Gq class)
46	321	183	4355	2425	4813	1178	4723	2240	843_at	protein tyrosine phosphatase type IVA, member 1
47	29	170	7282	6865	6155	523	402	583	40821_at	S-adenosylhomocysteine hydrolase
48	81	101	8352	6490	3444	308	737	623	1452_at	LIM domain only 4
49	11	2	2576	5715	3725	54	101	5	33415_at	non-metastatic cells 2, protein (NM23B) expressed in
50	72	311	1693	2506	930	41	79	313	32629_f_at	butyrophilin, subfamily 3, member A1
51	30	19	5994	5551	4154	846	652	1057	37147_at	stem cell growth factor; lymphocyte secreted C-type lectin

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
52	57	162	6231	6377	8551	232	225	1144	39932_at	Homo sapiens mRNA; cDNA DKFZp586F2224 (from clone DKFZp586F2224)
53	74	26	1585	1098	2297	47	35	17	1711_at	tumor protein p53-binding protein, l
54	274	21	3295	2921	3154	74	278	43	40141_at	cullin 4B
55	16	46	3687	5454	1826	1278	442	252	36537_at	Rho-specific guanine nucleotide exchange factor p114
56	62	33	5966	5635	7169	220	214	173	37986_at	erythropoietin receptor
57	55	24	1793	2145	4887	44	50	95	1403_s_at	small inducible cytokine A5 (RANTES)
58	185	201	5797	4517	2477	159	331	151	32843_s_at	fibrillarin
59	88	265	5254	3724	4435	202	170	565	39302_at	desmocollin 2
60	13	606	2770	1145	5922	82	11	771	38971_r_at	Nef-associated factor 1
61	40	40	5525	6158	6715	245	211	482	33757_f_at	pregnancy specific beta-1-glycoprotein 11
62	286	28	2620	2264	5008	83	236	142	31472_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
63	305	318	1023	2872	307	26	310	154	33637_g_at	cancer/testis antigen
64	184	190	4452	3255	3517	223	241	445	207_at	stress-induced-phosphoprotein 1 (Hsp70/Hsp90-organizing protein)
65	101	399	5221	4264	7422	249	206	798	40183_at	coactivator-associated arginine methyltransferase -1
66	91	56	2163	3116	3162	1969	1848	2792	40246_at	discs, large (Drosophila) homolog 1
67	19	370	2898	1532	2878	107	20	260	37280_at	MAD (mothers against decapentaplegic, Drosophila) homolog 1

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
68	71	911	2538	3388	5963	1680	1549	7785	39221_at	leukocyte immunoglobulin-like receptor, subfamily B (with TM and ITIM domains), member 2
69	203	7	437	440	929	3017	4275	466	32624_at	DKFZp566D133 protein
70	60	94	6844	6653	6358	785	640	425	***	NO .SIF_seq
71	76	817	4663	4498	5550	1073	1187	2548	36060_at	signal recognition particle 54kD
72	44	627	2530	2272	6120	113	52	402	40507_at	solute carrier family 2 (facilitated glucose transporter), member 1
73	58	307	4991	4702	5083	254	171	225	32211_at	proteasome (prosome, macropain) 26S subunit, non-ATPase, 13
74	46	825	3943	2954	8016	191	70	2586	36500_at	NAD(P) dependent steroid dehydrogenase-like; H105e3
75	264	397	5397	4257	7394	224	362	572	39865_at	Homo sapiens cDNA FLJ30639 fis, clone CTONG2002803
76	77	104	4288	5778	2331	1055	679	444	2035_s_at	enolase 1, (alpha)
77	97	373	2644	2657	5748	94	117	738	37572_at	cholecystokinin
78	45	111	5526	6106	3614	197	201	226	32254_at	vesicle-associated membrane protein 2 (synaptobrevin 2)
79	291	92	4357	7049	4748	188	790	202	41761_at	TIA1 cytotoxic granule-associated RNA-binding protein-like 1
80	242	233	8287	8066	7012	478	956	1963	36624_at	IMP (inosine monophosphate) dehydrogenase 2
81	133	240	1388	1748	1871	2911	2910	2622	37263_at	gamma-glutamyl hydrolase (conjugase, folylpolygamma glutamyl hydrolase)

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
82	103	175	2570	3861	4671	112	158	88	41224_at	KIAA0788 protein
83	64	250	917	955	1183	38	26	371	38087_s_at	S100 calcium-binding protein A4 (calcium protein, calvasculin, metastasin, murine placental homolog)
84	129	31	6589	4786	1770	417	305	13	35669_at	KIAA0633 protein
85	212	119	1435	3718	3729	2286	2573	2422	33433_at	DKFZP564F052 2 protein
86	183	244	5029	5157	5729	241	394	261	37441_at	lipoyltransferase
87	83	228	7786	7738	8485	451	283	1025	36002_at	KIAA1012 protein
88	120	548	7750	7722	7015	515	548	1968	36678_at	transgelin 2
89	42	139	1062	926	163	32	18	15	36129_at	KIAA0397 gene product
90	34	200	259	1166	25	15	19	10	32724_at	phytanoyl-CoA hydroxylase (Refsum disease)
91	65	57	4461	4427	4570	176	159	809	40435_at	solute carrier family 25 (mitochondrial carrier; adenine nucleotide translocator), member 6
92	132	68	2452	3105	1473	95	163	18	1923_at	cyclin C
93	70	142	6343	7528	7031	860	689	719	36835_at	protein kinase C-like 2
94	157	103	7459	4945	3449	738	1513	1241	1473_s_at	v-myb avian myeloblastosis viral oncogene homolog
95	158	410	585	1147	217	3710	3944	2837	41060_at	cyclin E1
96	240	277	6070	4715	4629	279	419	820	40859_at	Homo sapiens mRNA; cDNA DKFZp762G207 (from clone DKFZp762G207)
97	190	9	8035	6314	5815	574	560	542	38134_at	pleiomorphic adenoma gene 1
98	32	235	2988	3846	4106	145	55	515	36783_f_at	Krueppel-related zinc finger protein
99	259	437	5264	5003	4852	274	443	1646	1062_g_at	interleukin 10 receptor, alpha
100	227	823	2199	1173	4045	111	122	1035	36207_at	SEC14 (S. cerevisiae)-like 1

*** = AFFX-HUMGAPDH/M33197_M_at

Table 30. Lists of Most Uniformly Significant Genes
(Generated from 172 resampled Training and Test Data sets)

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
1	1	6	1	1	2	1	1	7	39418_at	DKFZP564M182 protein
2	8	2	3	8	1	2	8	2	41819_at	FYN-binding protein (FYB-120/130)
3	4	53	2	3	20	3	5	42	37981_at	drebrin 1
4	2	1	4	5	3	5	4	1	577_at	midkine (neurite growth-promoting factor 2)
5	5	5	5	9	5	4	6	3	37343_at	inositol 1,4,5-triphosphate receptor, type 3
6	9	44	7	6	23	7	9	71	32058_at	HNK-1 sulfotransferase
7	10	10	10	12	12	9	10	11	33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
8	12	31	14	20	13	8	12	66	1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
9	6	52	6	4	46	6	3	65	671_at	secreted protein, acidic, cysteine-rich (osteonectin)
10	13	23	9	14	15	11	14	35	32970_f_at	intracellular hyaluronan-binding protein
11	11	116	18	19	317	16	13	205	824_at	glutathione-S-transferase like; glutathione transferase omega
12	17	9	19	30	10	15	19	10	32724_at	phytanoyl-CoA hydroxylase (Refsum disease)
13	7	8	13	7	18	10	7	6	38652_at	hypothetical protein FLJ20154

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
14	22	41	15	27	39	13	24	40	36331_at	Homo sapiens mRNA; cDNA DKFZp586C091 (from clone DKFZp586C091)
15	19	30	8	13	24	14	17	32	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041
16	3	117	11	2	128	12	2	81	38119_at	glycophorin C (Gerbich blood group)
17	24	417	34	28	401	20	21	359	36927_at	hypothetical protein, expressed in osteoblast
18	38	81	27	49	71	18	33	53	35145_at	MAX binding protein
19	248	122	52	414	91	26	310	154	33637_g_at	cancer/testis antigen
20	15	186	92	71	558	38	26	371	38087_s_at	S100 calcium-binding protein A4 (calcium protein, calvasculin, metastasin, murine placental homolog)
21	104	643	23	118	275	28	120	1044	36576_at	H2A histone family, member Y
22	31	64	20	18	75	24	31	62	40523_at	hepatocyte nuclear factor 3, beta
23	40	12	12	21	7	17	29	12	34332_at	glucosamine-6-phosphate isomerase
24	60	180	16	46	134	21	59	314	32650_at	neuronal protein
25	960	21	31	599	9	19	767	9	41727_at	KIAA1007 protein
26	79	230	47	141	145	25	78	143	31527_at	ribosomal protein S2
27	83	60	36	105	55	22	62	27	38437_at	MLN51 protein
28	20	118	22	15	90	23	16	122	36524_at	Rho guanine nucleotide exchange factor (GEF) 4

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
29	56	70	49	90	116	43	77	165	36081_s_at	chromosome 21 open reading frame 18
30	47	191	37	38	106	33	41	294	160030_at	growth hormone receptor
31	102	146	42	111	113	30	86	168	36144_at	KIAA0080 protein
32	244	108	87	341	239	36	238	80	37748_at	KIAA0232 gene product
33	26	90	32	17	141	31	23	83	38270_at	poly (ADP-ribose) glycohydrolase
34	63	132	35	41	97	37	54	149	32623_at	gamma-aminobutyric acid (GABA) B receptor, 1
35	57	158	30	67	61	50	69	296	1676_s_at	eukaryotic translation elongation factor 1 gamma
36	165	61	21	121	50	34	149	28	38865_at	GRB2-related adaptor protein 2
37	28	157	74	63	171	76	43	310	324_f_at	NO .SIF_seq
38	84	3	59	119	4	54	101	5	33415_at	non-metastatic cells 2, protein (NM23B) expressed in
39	134	136	28	80	64	27	71	156	34171_at	hypothetical protein from EUROIMAGE 2021883
40	21	24	44	23	34	32	18	15	36129_at	KIAA0397 gene product
41	106	29	40	82	33	56	135	14	36004_at	Homo sapiens cDNA FLJ20586 fis, clone KAT09466, highly similar to AF091453 Homo sapiens NEMO protein
42	39	66	64	68	74	42	37	94	1189_at	cyclin-dependent kinase 8
43	48	154	50	51	92	44	50	95	1403_s_at	small inducible cytokine A5 (RANTES)

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
44	54	779	56	64	557	57	67	1022	35939_s_at	POU domain, class 4, transcription factor 1
45	30	379	67	47	429	60	38	246	35675_at	vinexin beta (SH3-containing adaptor molecule-1)
46	33	26	103	72	84	77	44	25	35856_r_at	glutamate receptor, ionotropic, kainate 1
47	37	516	55	43	265	49	40	442	1818_at	NO .SIF_seq
48	197	56	17	65	19	29	142	37	35059_at	Homo sapiens clone FBA1 Cri-du-chat region mRNA
49	65	37	71	92	45	39	53	78	36069_at	KIAA0456 protein
50	94	11	78	156	11	68	111	19	1980_s_at	non-metastatic cells 2, protein (NM23B) expressed in
51	81	147	45	79	63	46	75	150	32739_at	N-acetylglucosamine-phosphate mutase
52	115	85	51	112	144	51	114	57	361_at	B-cell CLL/lymphoma 9
53	100	256	39	96	112	41	79	313	32629_f_at	butyrophilin, subfamily 3, member A1
54	189	181	33	115	76	45	161	139	2062_at	insulin-like growth factor binding protein 7
55	55	106	29	34	60	35	36	121	36154_at	KIAA0263 gene product
56	88	566	48	99	291	52	84	663	32878_f_at	Homo sapiens cDNA FLJ32819 fis, clone TESTI200293 7, weakly similar to HISTONE H3.2
57	27	196	97	50	400	72	34	162	35796_at	protein tyrosine kinase 9-like (A6-related protein)

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
58	41	315	25	22	198	40	32	273	39518_at	Homo sapiens, clone MGC:9628 IMAGE:39133 11, mRNA, complete cds
59	92	33	65	107	30	58	90	39	35425_at	BarH-like homeobox 2
60	32	264	114	76	216	73	42	622	143_s_at	TAF5 RNA polymerase II, TATA box binding protein (TBP)-associated factor, 100 kD
61	91	59	26	52	28	55	85	52	34238_at	immunoglobulin superfamily, member 1
62	525	194	63	480	179	53	484	155	33866_at	tropomyosin 4
63	80	513	75	120	579	94	117	738	37572_at	cholecystokinin
64	34	459	70	53	336	80	49	1089	37961_at	phosphoinositide-3-kinase, regulatory subunit, polypeptide 3 (p55, gamma)
65	67	1046	94	97	610	92	95	1403	35201_at	heterogeneous nuclear ribonucleoprotein L
66	49	140	126	124	99	93	83	135	1255_g_at	guanylate cyclase activator 1A (retina)
67	62	67	95	62	88	63	56	54	35368_at	zinc finger protein 207
68	259	25	122	345	48	74	278	43	40141_at	cullin 4B
69	29	45	98	56	100	59	27	82	38124_at	midkine (neurite growth-promoting factor 2)
70	16	43	61	11	115	70	15	44	40617_at	hypothetical protein FLJ20274
71	35	1074	62	33	703	61	30	1527	38970_s_at	Nef-associated factor 1
72	42	84	41	25	65	48	28	84	38684_at	ATPase, Ca++ transporting, type 2C, member 1
73	50	207	68	37	180	66	47	283	41535_at	CDK2-associated protein 1

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
74	103	240	171	226	228	78	123	316	32703_at	serine/threonine kinase 18
75	46	4	83	32	8	62	39	4	36295_at	zinc finger protein 134 (clone pHZ-15)
76	123	988	79	171	757	64	115	1181	41208_at	S164 protein
77	93	394	167	242	242	103	138	481	33595_r_at	recombination activating gene 2
78	53	22	121	91	27	86	61	38	35414_s_at	jagged 1 (Alagille syndrome)
79	132	203	91	131	168	108	154	215	31353_f_at	forkhead box E2
80	161	16	43	93	17	69	151	23	35066_g_at	fetal hypothetical protein
81	374	231	86	428	201	71	369	247	35784_at	vesicle-associated membrane protein 3 (cellubrevin)
82	240	174	138	356	129	83	236	142	31472_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
83	86	82	84	100	138	67	68	112	34433_at	docking protein 1, 62kD (downstream of tyrosine kinase 1)
84	126	151	142	147	348	104	134	268	38105_at	hypothetical protein FLJ11021 similar to splicing factor, arginine/serine-rich 4
85	76	76	107	117	157	129	128	103	31722_at	ribosomal protein L3
86	52	77	38	31	41	65	45	51	34104_i_at	immunoglobulin heavy constant gamma 3 (G3m marker)
87	69	511	110	110	475	121	103	603	41825_at	PTEN induced putative kinase 1
88	25	261	93	29	276	91	25	417	41656_at	N-myristoyltransferase 2

In Training Data Set			In Test Data Set			In Overall Data Set			Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank		
89	36	696	184	77	1393	113	52	402	40507_at	solute carrier family 2 (facilitated glucose transporter), member 1
90	122	187	77	127	117	75	93	335	34760_at	KIAA0022 gene product
91	133	249	54	86	67	85	129	214	2092_s_at	secreted phosphoprotein 1 (osteopontin, bone sialoprotein I, early T-lymphocyte activation 1)
92	428	609	248	604	598	123	468	859	1160_at	cytochrome c-1
93	137	267	127	207	256	81	133	262	37563_at	KIAA0411 gene product
94	82	243	118	101	350	79	64	716	36647_at	hypothetical protein FLJ10326
95	718	568	174	1053	427	122	851	661	32841_at	zinc finger protein 9 (a cellular retroviral nucleic acid binding protein)
96	237	79	123	284	51	109	266	107	33469_r_at	complement factor H related 3
97	61	13	24	26	6	47	35	17	1711_at	tumor protein p53-binding protein, 1
98	136	302	46	98	103	89	137	231	32822_at	solute carrier family 25 (mitochondrial carrier; adenine nucleotide translocator), member 4
99	51	19	183	106	78	116	63	31	41252_s_at	Homo sapiens cDNA FLJ30436 fis, clone BRACE20090 37
100	71	414	53	42	252	87	58	693	34965_at	cystatin F (leukocystatin)

EXAMPLE X.

Threshold Independent Approach to Accessing Significance of OPAL1/G0 and OPAL1/G0-like genes

5 Threshold independent supervised learning algorithms (ROC) and Common Odds Ratio) were used to identify genes associated with outcome in the 167 member pediatric ALL training set described in Example II. Data were normalized using Helman-Veroff algorithm. Nonhuman genes and genes with all call being absent were removed from the data.

10 The following lists of genes associated with outcome (CCR vs. FAIL) were identified.

Table 31. ROC Curve Approach (Threshold Independent Method 1)

Top genes ranked in terms of ROC Accuracy

15

Rank	A	Access#	Gene Description						
1	0.7131	38652_at	hypothetical protein FLJ20154						
2*	0.6905	39418_at	DKFZP564M182 protein						
3	0.6667	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041						
4*	0.6653	37674_at	aminolevulinate, delta-, synthase 1						
5	0.6612	38270_at	poly (ADP-ribose) glycohydrolase						
6*	0.6572	671_at	secreted protein, acidic, cysteine-rich (osteonectin)						
7*	0.6546	1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds						
8*	0.6529	38119_at	glycophorin C (Gerbich blood group)						
9	0.6527	625_at	membrane protein of cholinergic synaptic vesicles						
10*	0.6524	31527_at	ribosomal protein S2						
11	0.6516	587_at	endothelial differentiation, sphingolipid G-protein-coupled receptor, 1						
12*	0.6513	36144_at	KIAA0080 protein						
13	0.6485	41819_at	FYN-binding protein (FYB-120/130)						
14	0.6454	36927_at	hypothetical protein, expressed in osteoblast						
15*	0.6451	34760_at	KIAA0022 gene product						
16	0.6434	37748_at	KIAA0232 gene product						
17	0.6433	33188_at	peptidylprolyl isomerase (cyclophilin)-like 2						
18*	0.6425	32336_at	aldolase A, fructose-bisphosphate						
19	0.6419	34349_at	SEC63 protein						
20*	0.6418	35796_at	protein tyrosine kinase 9-like (A6-related protein)						

* indicates low expression value predicts CCR

Table 32. Common Odds Ratio Approach (Threshold Independent Method 2)

Top genes ranked in terms of common odds ratio

Rank 1	Odds Ratio	Rank 2	A	Access#	Gene Description					
1	3.696	1	0.7131	38652_at	hypothetical protein FLJ20154					
2*	3.232	2	0.6905	39418_at	DKFZP564M182 protein					
3	2.725	3	0.6667	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041					
4*	2.696	4	0.6653	37674_at	aminolevulinate, delta-, synthase 1					
5	2.592	5	0.6612	38270_at	poly (ADP-ribose) glycohydrolase					
6*	2.575	6	0.6572	671_at	secreted protein, acidic, cysteine-rich (osteonectin)					
7*	2.558	7	0.6546	1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds					
8*	2.541	8	0.6529	38119_at	glycophorin C (Gerbich blood group)					
9	2.522	9	0.6527	625_at	membrane protein of cholinergic synaptic vesicles					
10*	2.512	12	0.6513	36144_at	KIAA0080 protein					
11	2.469	11	0.6516	587_at	endothelial differentiation, sphingolipid G-protein-coupled receptor, 1					
12*	2.449	10	0.6524	31527_at	ribosomal protein S2					
13*	2.441	15	0.6451	34760_at	KIAA0022 gene product					
14	2.426	16	0.6434	37748_at	KIAA0232 gene product					
15	2.413	14	0.6454	36927_at	hypothetical protein, expressed in osteoblast					
16	2.406	13	0.6485	41819_at	FYN-binding protein (FYB-120/130)					
17*	2.398	18	0.6425	32336_at	aldolase A, fructose-bisphosphate					
18*	2.367	24	0.6393	2062_at	insulin-like growth factor binding protein 7					
19	2.363	17	0.6433	33188_at	peptidylprolyl isomerase (cyclophilin)-like 2					

5 * indicates low expression value predicts CCR

Table 33. Comparison between several gene lists

Rank 1	A	Rank 2	Odds Ratio	Rank 3	F	p-value	Access#	
1	0.7131	1	3.696	1	23.327	0	38652_at	
2*	0.6905	2	3.232	2	14.964	0.00016	39418_at	
3	0.6667	3	2.725	5	13.543	0.00032	41478_at	
4*	0.6653	4	2.696	14	10.31	0.00159	37674_at	
5	0.6612	5	2.592	6	13.314	0.00035	38270_at	
6*	0.6572	6	2.575	4	13.886	0.00027	671_at	
7*	0.6546	7	2.558	20	10.037	0.00183	1126_s_at	
8*	0.6529	8	2.541	3	14.874	0.00016	38119_at	
9	0.6527	9	2.522	22	9.958	0.0019	625_at	
10*	0.6524	12	2.449	7	13.178	0.00038	31527_at	
11	0.6516	11	2.469	9	12.544	0.00052	587_at	
12*	0.6513	10	2.512	26	9.759	0.00211	36144_at	
13	0.6485	16	2.406	109	7.091	0.00851	41819_at	
14	0.6454	15	2.413	18	10.16	0.00172	36927_at	
15*	0.6451	13	2.441	10	10.867	0.0012	34760_at	
16	0.6434	14	2.426	198	5.68	0.0183	37748_at	
17	0.6433	19	2.363	161	6.039	0.01503	33188_at	
18*	0.6425	17	2.398	35	9.335	0.00262	32336_at	
19	0.6419	21	2.339	43	8.71	0.00363	34349_at	
20*	0.6418	27	2.278	8	12.545	0.00052	35796_at	

5 * indicates low expression value predicts CCR

Table 34. Comparison between several gene lists

Rank1	A1	Rank2	A2	Access #	Gene Description			
1	0.7093	1	0.713	38652_at	hypothetical protein FLJ20154			
2*	0.6931	4*	0.665	37674_at	aminolewulinate, delta-, synthase 1			
3	0.6865	3	0.667	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041			
4*	0.6776	50*	0.629	34433_at	docking protein 1, 62kD (downstream of tyrosine kinase 1)			
5*	0.6771	18*	0.643	32336_at	aldolase A, fructose-bisphosphate			
6*	0.6763	15*	0.645	34760_at	KIAA0022 gene product			
7	0.6723	108	0.618	40027_at	hypothetical protein			
8*	0.6685	7*	0.655	1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds			
9	0.6666	151	0.613	599_at	H2.0 (Drosophila)-like homeo box 1			
10*	0.666	49*	0.629	40817_at	nucleobindin 1			
11*	0.6642	69*	0.624	1403_s_at	small inducible cytokine A5 (RANTES)			
12	0.663	40	0.632	1452_at	LIM domain only 4			
13	0.6627	34	0.634	39607_at	myotubularin related protein 8			
14*	0.6623	110*	0.618	1062_g_at	interleukin 10 receptor, alpha			
15	0.6615	238	0.604	35260_at	KIAA0867 protein			
16*	0.6602	12*	0.651	36144_at	KIAA0080 protein			
17*	0.6573	2*	0.69	39418_at	DKFZP564M182 protein			
18	0.6562	268	0.603	39931_at	dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 3			
19	0.6558	22	0.64	38440_s_g	hypothetical protein			

Rank 1 and A1 are calculated based on the data with T-cell patients removed.

5 Rank 2 and A2 are calculated based on all 167 training data.

* indicates low expression value predicts CCR

Table 35. Comparison between several gene lists

Rank1	A1	Rank2	A2	Access#	Gene Description
1*	0.9615	666*	0.512	36808_at	splicing factor, arginine/serine-rich6
2	0.9231	160	0.612	33469_r_at	complement factor H-related 3
3	0.9135	719	0.582	31776_at	Human pre-T/NK cell associated protein (1F6) mRNA, 3 end
4	0.9071	548	0.588	36343_at	KIAA0328 protein
5	0.9071	392	0.595	33249_at	nuclear receptor subfamily 3, group C, member 2
6	0.9038	2720	0.549	33204_at	forkhead box D1
7	0.9005	860	0.579	32159_at	v-K-ras2 Kirsten rat sarcoma 2 viral oncogene homolog
8	0.9005	7992*	0.504	2021_s_at	cyclin E1
9	0.8974	2425	0.552	32525_r_at	hypothetical protein FLJ14529
10	0.8878	144	0.614	41727_at	KIAA1007 protein
11	0.8878	5788	0.521	34484_at	brefeldin A-inhibited guanine nucleotide exchange protein 2
12	0.8878	2466	0.552	34364_at	peptidylprolyl isomerase E (cyclophilin E)
13	0.8878	1938	0.559	40806_at	ELL-RELATED RNA POLYMERASE II, ELONGATION FACTOR
14	0.8814	842	0.579	36666_at	CD86 antigen (collagen type I receptor, thrombospondin receptor)
15	0.8782	7928	0.505	608_at	apolipoprotein E
16	0.875	779	0.581	40832_at	opiod growth factor receptor
17	0.875	2926	0.547	37238_s_at	membrane-associated tyrosine- and threonine-specific cdc2-inhibitory kinase
18	0.875	4024	0.535	36844_at	Homo sapiens, Similar to RIKEN cDNA 2600001B17 gene, clone IMAGE2822298, mRNA, partial cds
19*	0.8718	2*	0.69	39418_at	DKFZP564M182 protein

- 5 Rank 1 and A1 are calculated based on the T-cell data only.
Rank 2 and A2 are calculated based on all 167 training data.

- 10 The following tables represent consolidations of a number of different gene lists representing rankings in B-Cell and T-Cell data sets.

Table 36. Ranks of Significant Genes Generated in B-Cell, T-Cell and Overall Data Sets
(Genes are ordered on the A ranks in B-Cell Data)

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
1	1	1		7353	5095	6931		5	4	1		577_at	midkine (neurite growth-promoting factor 2)
2	2	27		7647	6799	7856		3	5	42		37981_at	drebrin 1
3	9	63		60	99	98		1	1	7		39418_at	DKFZP564M182 protein
4	3	33		7439	7001	5204		7	9	71		32058_at	HNK-1 sulfotransferase
5	4	17		8225	6463	4257		59	27	82		38124_at	midkine (neurite growth-promoting factor 2)
6	13	11		3914	2489	1617		2	8	2		41819_at	FYN-binding protein (FYB-120/130)
7	5	69		3694	7740	3025		16	13	205		824_at	glutathione-S-transferase like; glutathione transferase omega
8	6	51		2239	1452	1091		67	68	112		34433_at	docking protein 1, 62kD (downstream of tyrosine kinase 1)
9	8	7		1528	2577	824		44	50	95		1403_s_at	small inducible cytokine A5 (RANTES)
10	12	13		2701	2358	3492		9	10	11		33412_at	lectin, galactoside-binding, soluble, I (galectin I)
11	15	9		3492	4805	1951		15	19	10		32724_at	phytanoyl-CoA hydroxylase (Refsum disease)
12	10	21		6151	7120	7344		11	14	35		32970_f_at	intracellular hyaluronan-binding protein
13	17	6		7415	6374	6823		14	17	32		41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUJNG1000041
14	20	16		1635	1359	2448		4	6	3		37343_at	inositol 1,4,5-triphosphate receptor, type 3
15	7	59		8019	8350	7680		23	16	122		36524_at	Rho guanine nucleotide exchange factor (GEF) 4
16	26	29		5415	4331	1671		8	12	66		1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
17	14	91		5628	5194	4351		48	28	84		38684_at	ATPase, Ca++ transporting, type 2C, member 1
18	22	56		1444	1767	1145		340	668	117		35260_at	KIAA0867 protein
19	31	65		4131	4988	2772		143	124	194		40027_at	hypothetical protein
20	18	8		7175	5829	5050		47	35	17		1711_at	tumor protein p53-binding protein, 1

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
21	64	208		1890	4989	607		132	253	266		37674_at	aminolevulinate, delta-, synthase 1
22	52	55		3432	2281	2216		18	33	53		35145_at	MAX binding protein
23	32	10		5701	6669	5757		86	61	38		35414_s_at	jagged 1 (Alagille syndrome)
24	48	175		7697	7982	8415		41	79	313		32629_f_at	butyrophilin, subfamily 3, member A1
25	19	344		761	865	774		6	3	65		671_at	secreted protein, acidic, cysteine-rich (osteonectin)
26	45	174		5179	4943	7299		37	54	149		32623_at	gamma-aminobutyric acid (GABA) B receptor, 1
27	21	640		3961	6152	4056		20	21	359		36927_at	hypothetical protein, expressed in osteoblast
28	29	30		7179	6734	8385		42	37	94		1189_at	cyclin-dependent kinase 8
29	27	111		1401	1436	1894		171	92	306		32227_at	proteoglycan 1, secretory granule
30	77	238		1583	1643	795		274	443	1646		1062_g_at	interleukin 10 receptor, alpha
31	70	85		8373	8005	5864		30	86	168		36144_at	KIAA0080 protein
32	42	122		8022	8223	7494		75	93	335		34760_at	KIAA0022 gene product
33	11	40		8133	8431	8188		70	15	44		40617_at	hypothetical protein FLJ20274
34	44	57		7761	8070	7571		63	56	54		35368_at	zinc finger protein 207
35	24	39		1454	1520	2607		10	7	6		38652_at	hypothetical protein FLJ20154
36	38	117		5715	5390	5431		105	82	152		33362_at	Cdc42 effector protein 3
37	40	19		7440	5956	7128		95	163	18		1923_at	cyclin C
38	155	293		6855	6239	6001		200	612	257		37023_at	lymphocyte cytosolic protein 1 (L-plastin)
39	74	254		6737	7864	5349		52	84	663		32878_f_at	Homo sapiens cDNA FLJ32819 fis, clone TEST12002937, weakly similar to HISTONE H3.2
40	61	171		6463	6933	5257		175	205	460		32336_at	aldolase A, fructose-bisphosphate
41	54	271		2220	3427	2148		192	190	685		34481_at	vav 1 oncogene
42	72	608		5332	5119	3789		125	181	1408		35340_at	mel transforming oncogene (derived from cell line NK14) - RAB8 homolog
43	94	475		3397	2541	6535		430	1237	1143		39931_at	dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 3
44	103	185		4222	2988	5550		27	71	156		34171_at	hypothetical protein from EUROMAGE 2021883

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank	A Rank	F Rank	TNoM Rank	A Rank	F Rank	A Rank	F Rank	TNoM Rank			
45	35	25	5963	3969	7638	32	18	32	18	15	36129_at	KIAA0397 gene product	
46	37	123	5297	6905	3724	162	65	162	65	115	34889_at	ATPase, H+ transporting, lysosomal (vacuolar proton pump), alpha polypeptide, 70kD, isoform 1	
47	75	22	2740	2174	2125	17	29	17	29	12	34332_at	glucosamine-6-phosphate isomerase	
48	97	107	7195	6468	3221	83	236	83	236	142	31472_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds	
49	39	326	7834	7858	8167	118	96	118	96	401	40446_at	PHD finger protein 1	
50	16	210	297	414	624	12	2	12	2	81	38119_at	glycophorin C (Gerbich blood group)	

Table 37. Ranks of Significant Genes Generated in B-Cell, T-Cell and Overall Data Sets
(Genes are ordered on the ranks in T-Cell Data)

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
4227	4648	7022	1	4	19	872	941	2400	33141_at	hydroxysteroid (17-beta) dehydrogenase 1			
3417	2087	5974	2	1	2	8500	7256	6418	35808_at	splicing factor, arginine/serine-rich 6			
8473	8339	5826	3	3	10	4217	3608	5137	34327_at	SWI/SNF related, matrix associated, actin dependent regulator of chromatin, subfamily a, member 3			
459	3158	340	4	2	36	19	767	9	41727_at	KIAA1007 protein			
7881	8248	4494	5	11	11	2600	2695	4094	34364_at	peptidylprolyl isomerase E (cyclophilin E)			
4905	2975	864	6	16	27	7007	8506	4106	34484_at	brefeldin A-inhibited guanine nucleotide-exchange protein 2			
7078	6036	1760	7	6	69	2709	2150	2447	33878_at	hypothetical protein FLJ13612			
8103	8490	2366	8	19	20	3142	4146	936	33204_at	forkhead box D1			

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
7007	8397	6795		9	21	3		3279	3018	7118		160022_at	colony stimulating factor 1 receptor, formerly McDonough feline sarcoma viral (v-fms) oncogene homolog
3913	5807	5248		10	7	33		651	1741	590		41248_at	likely ortholog of mouse variant polyadenylation protein CSTF-64
4933	4225	1734		11	5	7		987	1078	1820		33523_at	alkaline phosphatase, intestinal
1131	1246	2410		12	25	24		6050	5789	5100		33848_r_at	cyclin-dependent kinase inhibitor 1B (p27, Kipl)
702	1080	180		13	81	6		109	266	107		33469_r_at	complement factor H related 3
1767	934	2781		14	9	99		531	265	3543		39423_f_at	sortilin-related receptor, L(DLR class) A repeats-containing
7380	7385	4988		15	45	95		3353	4297	378		38981_at	NADH dehydrogenase (ubiquinone) 1 beta subcomplex, 3 (12kD, B12)
6933	6743	8142		16	18	9		1958	1879	2443		33841_at	hypothetical protein FLJ11560
4189	4746	8069		17	15	17		1009	1432	3069		32524_s_at	hypothetical protein FLJ14529
4835	4238	4281		18	13	4		1236	1311	4953		32159_at	v-Ki-ras2 Kirsten rat sarcoma 2 viral oncogene homolog
2075	2706	824		19	8	57		252	388	105		32707_at	katanin p60 (ATPase-containing) subunit A 1
8356	5954	7079		20	101	8		3544	2120	6238		33710_at	putative protein similar to nesso (Drosophila)
5756	5167	5700		21	216	5		5820	7418	6196		33259_at	semenogelin II
8044	5787	6955		22	42	18		3536	2270	6130		32525_r_at	hypothetical protein FLJ14529
3251	2715	7856		23	50	312		981	820	2853		41276_at	sin3-associated polypeptide, 18kD
6319	7703	3893		24	47	13		1820	3337	130		40332_at	opioid growth factor receptor
3443	4786	4018		25	23	35		936	1573	839		41650_at	Homo sapiens cDNA FLJ31861 fis, clone NT2RP7001319
8248	8233	7137		26	30	25		3962	3430	7388		34340_at	cytochrome b5 outer mitochondrial membrane precursor
7589	6840	5732		27	62	64		3052	2012	946		33514_at	calcium/calmodulin-dependent protein kinase IV
4330	3220	4320		28	31	56		1286	959	3067		32520_at	nuclear receptor subfamily 1, group D, member 1

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
1691	1545	2690	29	106	12	422	464	756	38343_at	KIAA0328 protein			
6441	6847	4723	30	10	234	5264	5548	3346	36656_at	CD36 antigen (collagen type I receptor, thrombospondin receptor)			
7508	8315	5679	31	29	60	3200	3632	5028	33056_at	endonuclease G-like 2			
4643	2514	7830	32	69	14	1238	584	5804	41010_at	Homer, neuronal immediate early gene, 1B			
599	937	674	33	199	90	692	722	1107	38545_at	inhibin, beta B (activin AB beta polypeptide)			
7770	4260	7989	34	12	15	2026	933	2286	1496_at	protein tyrosine phosphatase, receptor type, A			
3888	3837	2088	35	27	32	6483	7269	4626	40755_at	MHC class I polypeptide-related sequence A			
7021	7032	3878	36	55	104	4386	4289	5702	400_at	insulin promoter factor 1, homeodomain transcription factor			
2560	3586	6450	37	46	103	552	1082	2127	40006_at	sialyltransferase 4B (beta-galactosidase alpha-2,3-sialyltransferase)			
520	355	282	38	65	78	77	44	25	35856_r_at	glutamate receptor, ionotropic, kainate 1			
6991	5758	6881	39	73	16	2798	2155	4910	31627_f_at	amine oxidase, copper containing 3 (vascular adhesion protein 1)			
3229	1662	1989	40	20	266	8368	7230	5560	38719_at	N-ethylmaleimide-sensitive factor			
6541	4081	1331	41	120	232	3084	1584	1447	36573_at	DEAD/H (Asp-Glu-Ala-Asp/His) box binding protein 1			
5103	6423	6115	42	22	83	6302	5531	6548	37152_at	peroxisome proliferative activated receptor, delta			
4017	2364	8554	43	14	319	1597	812	7024	41840_r_at	Homo sapiens clone IMAGE 25997			
404	339	1131	44	64	1	33	41	294	160030_at	growth hormone receptor			
5163	4910	1442	45	24	272	1553	1714	382	39198_s_at	CGI-87 protein			
1281	946	1421	46	91	91	296	213	764	38741_at	pleckstrin homology, Sec7 and coiled/coil domains 2-like			
5170	2594	1027	47	148	101	5261	8400	2776	39844_at	Homo sapiens, Similar to RIKEN cDNA 2600001B17 gene, clone IMAGE:2822298, mRNA, partial cds			
154	223	38	48	108	222	39	53	78	36069_at	KIAA0456 protein			
3290	3985	4509	49	39	189	858	1170	975	34465_at	retinoschisis (X-linked, juvenile) 1			
6433	3468	4504	50	122	26	2185	976	6308	34426_at	major histocompatibility complex, class I-like sequence			

Table 38. Ranks of Significant Genes Generated in B-Cell, T-Cell and Overall Data Sets
(Genes are ordered on the A ranks in Overall Data)

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
3	9	63		60	99	98		1	1	7		39418_at	DKFZP564M182 protein
6	13	11		3914	2489	1617		2	8	2		41819_at	FYN-binding protein (FYB-120/130)
2	2	27		7647	6799	7856		3	5	42		37981_at	drebrin 1
14	20	16		1635	1359	2448		4	6	3		37343_at	inositol 1,4,5-triphosphate receptor, type 3
1	1	1		7353	5095	6931		5	4	1		577_at	midkine (neurite growth-promoting factor 2)
25	19	344		761	865	774		6	3	65		671_at	secreted protein, acidic, cysteine-rich (osteonectin)
4	3	33		7439	7001	5204		7	9	71		32058_at	HNK-1 sulfotransferase
16	26	29		5415	4331	1671		8	12	66		1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
10	12	13		2701	2358	3492		9	10	11		33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
35	24	39		1454	1520	2607		10	7	6		38652_at	hypothetical protein FLJ20154
12	10	21		6151	7120	7344		11	14	35		32970_f_at	intracellular hyaluronan-binding protein
50	16	210		297	414	624		12	2	81		38119_at	glycophorin C (Gerbich blood group)
88	184	86		837	444	1212		13	24	40		36331_at	Homo sapiens mRNA; cDNA DKFZp586C091 (from clone DKFZp586C091)
13	17	6		7415	6374	6823		14	17	32		41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041
11	15	9		3492	4805	1951		15	19	10		32724_at	phytanoyl-CoA hydroxylase (Refsum disease)
7	5	69		3694	7740	3025		16	13	205		824_at	glutathione-S-transferase like; glutathione transferase omega
47	75	22		2740	2174	2125		17	29	12		34332_at	glucosamine-6-phosphate isomerase
22	52	55		3432	2281	2216		18	33	53		35145_at	MAX binding protein
459	3158	340		4	2	36		19	767	9		41727_at	KIAA1007 protein
27	21	640		3961	6152	4056		20	21	359		36927_at	hypothetical protein, expressed in osteoblast

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
185	318	821		446	491	424		21	59	314		32650_at	neuronal protein
181	414	137		281	313	1354		22	62	27		38437_at	MLN51 protein
15	7	59		8019	8350	7680		23	16	122		36524_at	Rho guanine nucleotide exchange factor (GEF) 4
247	242	150		132	158	301		24	31	62		40523_at	hepatocyte nuclear factor 3, beta
112	210	362		1610	1034	1839		25	78	143		31527_at	ribosomal protein S2
159	832	262		1147	990	464		26	310	154		33637_g_at	cancer/testis antigen
44	103	185		4222	2988	5550		27	71	156		34171_at	hypothetical protein from EUROMAGE 2021883
77	216	1883		1706	1656	3994		28	120	1044		36576_at	H2A histone family, member Y
74	264	54		3350	2695	3750		29	142	37		35059_at	Homo sapiens clone FBA1 Cri-du-chat region mRNA
31	70	85		8373	8005	5864		30	86	168		36144_at	KIAA0080 protein
226	116	668		304	181	637		31	23	83		38270_at	poly (ADP-ribose) glycohydrolase
45	35	25		5963	3969	7638		32	18	15		36129_at	KIAA0397 gene product
404	339	1131		44	64	1		33	41	294		160030_at	growth hormone receptor
94	137	215		749	5206	653		34	149	28		38865_at	GRB2-related adaptor protein 2
133	136	286		1442	957	2329		35	36	121		36154_at	KIAA0263 gene product
56	336	90		3557	3257	4183		36	238	80		37748_at	KIAA0232 gene product
26	45	174		5179	4943	7299		37	54	149		32623_at	gamma-aminobutyric acid (GABA) B receptor, 1
54	43	447		3621	2573	4252		38	26	371		38087_s_at	S100 calcium-binding protein A4 (calcium protein, calvasculin, metastasin, murine placental homolog)
154	223	38		48	108	222		39	53	78		36069_at	KIAA0456 protein
337	207	2027		102	87	674		40	32	273		39518_at	Homo sapiens, clone MGC:9628 IMAGE:3913311, mRNA, complete cds
24	48	175		7697	7982	8415		41	79	313		32629_f_at	butyrophilin, subfamily 3, member A1
28	29	30		7179	6734	8385		42	37	94		1189_at	cyclin-dependent kinase 8
106	126	84		425	1480	1194		43	77	165		36081_s_at	chromosome 21 open reading frame 18
9	8	7		1528	2577	824		44	50	95		1403_s_at	small inducible cytokine A5 (RANTES)

In B-Cell Data Set				In T-Cell Data Set				In Overall Data Set				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
84	171	245		7903	5919	3193		45	161	139		2062_at	insulin-like growth factor binding protein 7
63	98	114		4077	4359	979		46	75	150		32739_at	N-acetylglucosamine-phosphate mutase
20	18	8		7175	5829	5050		47	35	17		1711_at	tumor protein p53-binding protein, 1
17	14	91		5628	5194	4351		48	28	84		38684_at	ATPase, Ca+++ transporting, type 2C, member 1
202	194	526		174	85	43		49	40	442		1818_at	NO_SIF_seq
373	415	523		299	310	131		50	69	296		1676_s_at	eukaryotic translation elongation factor 1 gamma

Table 39. Ranks of Uniformly Significant Genes Generated in Data Sets with T-Cell Data Removed

In Random Training Set				In Random Test Set				In Overall B-Cell Data				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
1	1	1		1	1	1		1	1	1		577_at	midkine (neurite growth-promoting factor 2)
2	2	25		2	5	21		2	2	27		37981_at	drebrin 1
3	8	44		6	21	86		3	9	63		39418_at	DKFZP564M182 protein
4	15	7		11	19	8		6	13	11		41819_at	FYN-binding protein (FYB-120/130)
5	3	19		4	3	20		5	4	17		38124_at	midkine (neurite growth-promoting factor 2)
6	4	26		3	2	6		4	3	33		32058_at	HNK-1 sulfotransferase
7	7	53		10	9	32		8	6	51		34433_at	docking protein 1, 62kD (downstream of tyrosine kinase 1)
8	9	12		16	17	13		9	8	7		1403_s_at	small inducible cytokine A5 (RANTES)
9	5	54		5	4	80		7	5	69		824_at	glutathione-S-transferase like; glutathione transferase omega
10	6	40		15	8	43		15	7	59		36524_at	Rho guanine nucleotide exchange factor (GEF) 4
11	12	6		18	24	4		11	15	9		32724_at	phytanoyl-CoA hydroxylase (Refsum disease)

In Random Training Set				In Random Test Set				In Overall B-Cell Data				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
12	17	11		13	14	7		14	20	16		37343_at	inositol 1,4,5-trisphosphate receptor, type 3
13	13	18		7	10	16		10	12	13		33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
14	11	17		9	6	12		12	10	21		32970_f_at	intracellular hyaluronan-binding protein
15	20	10		12	12	17		13	17	6		41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041
16	26	15		14	25	9		16	26	29		1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
17	22	62		8	11	33		17	14	91		38684_at	ATPase, Ca++ transporting, type 2C, member 1
18	23	63		17	15	45		18	22	56		35260_at	KIAA0867 protein
19	31	85		20	26	100		19	31	65		40027_at	hypothetical protein
20	18	5		21	16	2		20	18	8		1711_at	tumor protein p53-binding protein, 1
21	14	208		32	29	417		25	19	344		671_at	secreted protein, acidic, cysteine-rich (osteonectin)
22	69	99		23	75	93		21	64	208		37674_at	aminolevulinatase, delta-, synthase 1
23	49	68		19	48	44		22	52	55		35145_at	MAX binding protein
24	30	31		44	42	27		28	29	30		1189_at	cyclin-dependent kinase 8
25	39	140		28	51	47		26	45	174		32623_at	gamma-aminobutyric acid (GABA) B receptor, 1
26	50	103		27	46	57		24	48	175		32629_f_at	butyrophilin, subfamily 3, member A1
27	56	469		43	88	737		42	72	608		35340_at	mel transforming oncogene (derived from cell line NK14)- RAB8 homolog
28	74	171		26	70	96		30	77	238		1062_g_at	interleukin 10 receptor, alpha
29	21	384		29	20	457		27	21	640		36927_at	hypothetical protein, expressed in osteoblast
30	34	8		22	23	3		23	32	10		35414_s_at	jagged 1 (Alagille syndrome)
31	27	60		25	28	38		29	27	111		32227_at	proteoglycan 1, secretory granule
32	147	159		42	216	277		38	155	293		37023_at	lymphocyte cytosolic protein 1 (L-plastin)

In Random Training Set				In Random Test Set				In Overall B-Cell Data				Accession #	Gene Description
A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank		A Rank	F Rank	TNoM Rank			
33	46	59		41	71	88		32	42	122		34760_at	KIAA0022 gene product
34	36	65		38	41	90		34	44	57		35368_at	zinc finger protein 207
35	10	36		37	7	67		33	11	40		40617_at	hypothetical protein FLJ20274
36	58	123		40	84	152		40	61	171		32336_at	aldolase A, fructose-bisphosphate
37	24	41		48	27	78		35	24	39		38652_at	hypothetical protein FLJ20154
38	93	95		24	78	79		31	70	85		36144_at	KIAA0080 protein
39	44	27		35	39	35		37	40	19		1923_at	cyclin C
40	33	21		54	36	31		45	35	25		36129_at	KIAA0397 gene product
41	63	296		34	45	221		41	54	271		34481_at	vav 1 oncogene
42	97	657		33	86	404		51	113	772		1637_at	mitogen-activated protein kinase-activated protein kinase 3
43	45	184		31	40	170		36	38	117		33362_at	Cdc42 effector protein 3
44	72	20		39	76	18		47	75	22		34332_at	glucosamine-6-phosphate isomerase
45	100	161		52	128	123		44	103	185		34171_at	hypothetical protein from EUROIMAGE 2021883
46	79	368		45	68	248		39	74	254		32878_f_at	Homo sapiens cDNA FLJ32819 fis, clone TEST12002937, weakly similar to HISTONE H3.2
47	102	397		49	98	428		43	94	475		39931_at	dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 3
48	16	261		55	18	329		50	16	210		38119_at	glycophorin C (Gerbich blood group)
49	323	96		83	348	292		56	336	90		37748_at	KIAA0232 gene product
50	42	401		66	55	623		54	43	447		38087_s_at	S100 calcium-binding protein A4 (calcium protein, calvasculin, metastasin, murine placental homolog)

EXAMPLE XI.

Correlated Gene Lists for Outcome Prediction in Pre-B ALL Cohort

Introduction. This Example summarizes and correlates selected gene
5 lists predictive of outcome (specifically, CCR vs. Failure) obtained for the pre-
B ALL cohort described in Example IB. "Task 2" refers to CCR vs. FAIL for
B-cell + T-cell patients; "Task 2a" is CCR vs. FAIL for B-cell only patients.
Gene lists selected for evaluation were produced by the following methods: (1)
a compilation of genes identified using feature selection combined with a
10 supervised learning techniques such as SVM/RFE, Discriminant Analysis/t-test,
Fuzzy Inference/rank-ordering statistics, and Bayesian Nets/TNoM; note that
SVM/RFE and Bayesian Net/TNoM are both multivariate (MV) gene selection
techniques; the others are univariate; (2) TNoM gene selection; (3) supervised
classification; (4) empirical CDF/MaxDiff method; (5) threshold independent
15 approach; (6) GA/KNN; (7) uniformly significant genes via resampling; (8)
ANOVA "gene contrast" lists derived via VxInsight.

The techniques fall into two broad categories, which we have termed
univariate and *multivariate*.

- 20 *Group 1 (univariate).* These methods evaluate the significance of a given gene
in contributing to outcome discrimination on an individual basis. They include:
- two-sample *t*-test (here equivalent to *F*-test or one-way ANOVA)
 - Rank-ordering statistics
 - ROC curves ("threshold-independent method 1")
 - 25 ◦ Common odds ratio approach ("threshold-independent method 2")
 - "Most uniformly significant genes" via resampling – average rank from
172 train/test resamplings of the dataset, for each of 3 different methods:
F-test, ROC accuracy A, and TNoM score;
 - GA/KNN
 - 30 ◦ Empirical cumulative distribution function (CDF) MaxDiff approach
 - TNoM method– used to pre-filter genes for use as parent sets in
constructing (and scoring) competing Bayesian nets that best explain the
training set data.

Group 2 (multivariate). These methods identify *groups* of genes that act in concert to discriminate outcome. The optimal gene groups are determined via an iterative (SVM, stepwise DA) or combinatoric exploration (Bayesian) procedure. They include:

5

- SVM/RFE (Support Vector Machines with Recursive Feature Elimination)
- Bayesian net evaluation of (via BD metric) of highest-scoring parent sets (gene combinations)

10

- Stepwise discriminant analysis

The top genes in each group are identified and to determine how often the same genes turn up repeatedly within each group. The following two tables correspond to Tasks 2 (Table 40) and 2a (Table 41). The top 20 genes found in

15

Table 40 are listed in Table 42 with more detailed annotations.

Table 40. Task 2 (CCR vs. FAIL, full dataset of pre-B and T-cell cases)

Univariate and multivariate (MV) methods. comparative gene rankings:

Bayesian Net-derived G0, G1, G2 (MV) indicated in yellow

All methods used training set only, except for the method of column 1, which used combined train/test set, and gave results comparable to 172 resampled training sets ("uniformly most significant genes"), and column 3, ANOVA (VxInsight "User Contrast").

Gene descriptions are from Affy Complete Entry (in some cases supplemented by additional/different information provided by analysts, in parentheses)

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNom	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REE (MV)	Affy Accession #	Description
1	4	1		3	2		15			39418_at	DKFZP564M182 protein
2		19	12		13		9			41819_at	FYN-binding protein (FYB-120/130)
3		2								37981_at	drebrin 1
5		6								577_at	midkine (neurite growth- promoting factor 2)
4	5	7	21			26				37343_at	inositol 1,4,5-triphosphate receptor, type 3
7		20								32058_at	HNK-1 sulfotransferase
9									5	33412_at	lectin, galactoside-binding, soluble, 1 (galectin 1)
8	22	8	13	15	7					1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
6		5		4	6	3	13	2	19	671_at	secreted protein, acidic, cysteine-rich (osteonectin)

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNom	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SYM/REFE (MV)	Affy Accession #	Description
11		9				20				32970_f_at	intracellular hyaluronan- binding protein
16		13				4				824_at	glutathione-S-transferase like; glutathione transferase omega
15										32724_at	phytanoyl-CoA hydroxylase (Refsum disease)
10	1	12	1	1	1	1	1	1	2	38652_at	hypothetical protein FLJ20154 (aka hypothetical protein FLJ20367, NM_017787) (G0)
13										36331_at	Homo sapiens mRNA; cDNA DKFZp586C091 (from clone DKFZp586C091)
14			23	5	3	7	24		10	41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041
12	11	4		2	8	13				38119_at	glycophorin C (Gerbich blood group) (NM_002101 analysis glycophorin C isoform 1 NM_016815 analysis glycophorin C isoform 2)
20				17	14			4	6	36927_at	hypothetical protein, expressed in osteoblast
18										35145_at	MAX binding protein
26	14									33637_g_at	cancer/testis antigen

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNoM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/RFE (MV)	Affy Accession #	Description
										34610_at	guanine nucleotide binding protein (G protein), beta polypeptide 2-like 1 (G1)
										35659_at	interleukin 10 receptor, alpha (G2)
	2									38585_at	hemoglobin gamma A
	3									35965_at	heat shock 70kD protein 6 HSP70B
	6									32557_at	U2 small nuclear ribonucleoprotein auxiliary factor 65kD
	7									40435_at	solute carrier family 25 (mitochondrial carrier; adenine nucleotide translocator), member 6
	8		8			27	17			32624_at	DKFZp566D133 protein (likely ortholog of mouse tuberin-like protein 1)
	9		2							33415_at	non-metastatic cells 2 protein NM23B expressed in
	10		5							41559_at	Homo sapiens, clone IMAGE:3880654, mRNA
	12		29							31472_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
	13									38750_at	Notch Drosophila homolog 3
	15		6							1980_s_at	non-metastatic cells 2 protein NM23B expressed

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNoM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SYM/REE (MV)	Affy Accession #	Description
											in
	16									32703_at	serine/threonine kinase 18
	17	23	25				3			1403_s_at	small inducible cytokine A5 RANTES (chemokine (C-C motif) ligand 5)
	18									2091_at	wingless-type MMTV integration site family, member 4
	19									36624_at	IMP inosine monophosphate dehydrogenase 2
	20									176_at	protein phosphatase 2 regulatory subunit B B56 gamma isoform
	21									38794_at	upstream binding transcription factor RNA polymerase I
	23						5			37986_at	erythropoietin receptor precursor
	24									36386_at	pyruvate dehydrogenase kinase isoenzyme 1
	25									38865_at	GRB2-related adaptor protein 2
		3		9						38971_r_at	Nef-associated factor 1
		10								41185_f_at	SMT3 (suppressor of mif two 3, yeast) homolog 2
		11								33362_at	Cdc42 effector protein 3
		14	18	6	20	5				35796_at	protein tyrosine kinase 9- like (A6-related protein)

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNoM	HK F. test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REE (NIV)	Affy Accession #	Description
		15								40523_at	hepatocyte nuclear factor 3, beta
24		16								37184_at	syntaxin 1A (brain)
		17								34890_at	ATPase, H+ transporting, lysosomal (vacuolar proton pump), alpha polypeptide, 70kD, isoform 1
		18								41257_at	type 1 tumor necrosis factor receptor shedding aminopeptidase regulator (NM_001750 analysis calpastatin)
		21								38970_s_at	Nef-associated factor 1
		22								34809_at	KIAA0999 protein (hypothetical protein FLJ12240)
		24								33866_at	tropomyosin 4
17		25								34332_at	glucosamine-6-phosphate isomerase
			3							36012_at	PIBF1 gene product (progesterone-induced blocking factor 1)
			4							38838_at	polymyositis/scleroderma autoantigen 1 (75kD)
			7							31444_s_at	annexin A2 pseudogene 3
			9							36295_at	zinc finger protein 134 (clone pHZ-15)
			10							38134_at	pleiomorphic adenoma gene 1

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (V ₁ "User Contrast")	RV/PH TNoM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SYM/REE (MV)	Affy Accession #	Description
			11	7	5	12			18	38270_at	poly (ADP-ribose) glycohydrolase
			14				19			32224_at	KIAA0769 gene product
			15	19	18					32336_at	aldolase A, fructose- biphosphate
			16							32398_s_at	low density lipoprotein receptor-related protein 8, apolipoprotein e receptor
			17							35756_at	chromosome 19 open reading frame 3 (regulator of G-protein signalling 19 interacting protein 1)
			19	14				7		36154_at	KIAA0263 gene product
			20			14				37147_at	stem cell growth factor; lymphocyte secreted C-type lectin
			22							40141_at	cullin 4B
19			24							41727_at	KIAA1007 protein
			26							1488_at	protein tyrosine phosphatase, receptor type, K
			27							1711_at	tumor protein p53-binding protein, l
			28							307_at	arachidonate 5- lipoxigenase
			30							31473_s_at	tankyrase, TRF1- interacting ankyrin-related ADP-ribose polymerase
				8	11	2			11	587_at	endothelial differentiation,

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNom	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SV/MREE (MV)	Affy Accession #	Description
											sphingolipid G-protein- coupled receptor, 1
				10	15			3	29	34760_at	KIAA0022 gene product
25				11	10					31527_at	ribosomal protein S2
				12	4	19				37674_at	Aminolevulinate, delta-, synthase 1
				13	12		8	6	21	36144_at	KIAA0080 protein
				16						31695_g_at	regulatory solute carrier protein, family 1, member 1
				18						34965_at	cystatin F (leukocystatin)
				20	9	9		5	14	625_at	membrane protein of cholinergic synaptic vesicles
					16					37748_at	KIAA0232 gene product
					17					33188_at	peptidylprolyl isomerase (cyclophilin)-like 2
					19			9		34349_at	SEC63 protein
						8		11		40817_at	nucleobindin 1
						24				2065_s_at	BCL2-associated X protein
						25				404_at	interleukin 4 receptor
							2	25		35991_at	Sm protein F
							4			41097_at	telomeric repeat binding factor 2
							6			40276_at	proteasome (prosome, macropain) 26S subunit, non-ATPase, 7 (Mov34 homolog)

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNoM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SYM/REE (MV)	Affy_Accession #	Description
							7			40272_at	collapsin response mediator protein 1
							10			40898_at	sequestosome 1
							11			33229_at	ribosomal protein S6 kinase, 90kD, polypeptide 3
							12			35633_at	engulfment and cell motility 1 (ced-12 homolog, C. elegans)
							14			514_at	Cas-Br-M (murine) ectropic retroviral transforming sequence b
							16			38155_at	origin recognition complex, subunit 5 (yeast homolog)- like
							18			32227_at	proteoglycan 1, secretory granule
							20			40953_at	calponin 3, acidic
							21			41188_at	putative integral membrane transporter
							22			39552_at	phosphatase and tensin homolog (mutated in multiple advanced cancers 1)
							23			2062_at	insulin-like growth factor binding protein 7
							25			746_at	phosphodiesterase 3B, cGMP-inhibited
								8		36783_f_at	Krueppel-related zinc

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNoM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/RFE (MV)	Affy Accession #	Description
											finger protein
								10		36500_at	NAD(P) dependent steroid dehydrogenase-like; H105e3
								12	1	39932_at	Homo sapiens mRNA; cDNA DKFZp586F2224 (from clone DKFZp586F2224)
								13		35241_at	KIAA0335 gene product
								14		38350_f_at	tubulin, alpha 2
								15		33595_r_at	recombination activating gene 2
								16		40446_at	PHD finger protein 1
								17	24	1368_at	interleukin 1 receptor, type 1
								18		1077_at	recombination activating gene 1
								19		207_at	stress-induced- phosphoprotein 1 (Hsp70/Hsp90-organizing protein)
								20		32778_at	inositol 1,4,5-triphosphate receptor, type 1
								21		1479_g_at	IL2-inducible T-cell kinase
								22		35425_at	BarH-like homeobox 2
								23		39430_at	tankyrase, TRF1- interacting ankyrin-related ADP-ribose polymerase

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNoM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/RFE (MV)	Affy Accession #	Description
								24		40742_at	hemopoietic cell kinase
									3	33957_at	HCGII-7 protein
									4	36577_at	mitogen inducible 2
									7	39696_at	paternally expressed 10
									8	34710_r_at	ESTs
									9	31407_at	protease, serine, 7 (enterokinase)
									12	35669_at	K1AA0633 protein
									13	39221_at	leukocyte immunoglobulin- like receptor, subfamily B (with TM and ITIM domains), member 2
									15	38840_s_at	profilin 2
									16	35961_at	Homo sapiens mRNA; cDNA DKFZp586O1318 (from clone DKFZp586O1318)
									17	37280_at	MAD (mothers against decapentaplegic, Drosophila) homolog 1
									20	38111_at	chondroitin sulfate proteoglycan 2 (versican)
									22	33914_r_at	ferrochelatase (protoporphyrin)
									23	35614_at	transcription factor-like 5 (basic helix-loop-helix)
									25	36342_r_at	H factor (complement)-like 3

HK ROC- accuracy- selected genes, overall dataset	SM Empirical CDF MaxDiff	GD ANOVA (Vx "User Contrast")	RV/PH TNOM	HK F- test, Table 3	HK Threshold- Independent Method 1 (ROC Curves)	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/RFE (MV)	Affy Accession #	Description
									27	106_at	runt-related transcription factor 3
									28	38514_at	immunoglobulin lambda- like polypeptide 1
									30	38940_at	AD024 protein

Table 41. Task 2a (CCR vs. FAIL, pre-B cases only)

Same notation, etc. as Task 2

SM ANOVA (V1 "User Contrast")	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REE (MV)	Affy Accession #	Description
1					577_at	midkine (neurite growth- promoting factor 2)
2					41819_at	FYN-binding protein (FYB- 120/130)
3					37981_at	drebrin 1
4					32058_at	HNK-1 sulfotransferase
5					39418_at	DKFZP564M182 protein
6			16	11	32970_f_at	intracellular hyaluronan-binding protein
7	12		2	1	34433_at	docking protein 1, 62kD (downstream of tyrosine kinase 1)
8	3				38971_r_at	Nef-associated factor 1
9					38124_at	midkine (neurite growth- promoting factor 2)
10					36524_at	Rho guanine nucleotide exchange factor (GEF) 4
11					824_at	glutathione-S-transferase like; glutathione transferase omega
12					34809_at	KIAA0999 protein
13					38119_at	glycophorin C (Gerbich blood group)
14					37343_at	inositol 1,4,5-triphosphate receptor, type 3

SM ANOVA (V1 "User Contrast")	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/RFE (MV)	Affy Accession #	Description
15	11	1			1403_s_at	small inducible cytokine A5 (RANTES)
16					33362_at	Cdc42 effector protein 3
17	5	13			41478_at	Homo sapiens cDNA FLJ30991 fis, clone HLUNG100041
18					671_at	secreted protein, acidic, cysteine-rich (osteonectin)
19					35260_at	KIAA0867 protein
20					37364_at	B-cell associated protein
21					38940_at	AD024 protein
22					1062_g_at	interleukin 10 receptor, alpha
23	10				37184_at	syntaxin 1A (brain)
24					32724_at	phytanoyl-CoA hydroxylase (Refsum disease)
25					1126_s_at	Homo sapiens CD44 isoform RC (CD44) mRNA, complete cds
26					31538_at	ribosomal protein, large, P0
27					40617_at	hypothetical protein FLJ20274
28	1	6	1	2	38652_at	hypothetical protein FLJ20154 (G0)
29					38203_at	potassium intermediate/small conductance calcium-activated channel, subfamily N, member 1
30	6				40027_at	hypothetical protein
	2	28	3		34760_at	KIAA0022 gene product
	4				37674_at	aminolevulinate, delta-, synthase 1
	7		9		2065_s_at	BCL2-associated X protein

SM ANOVA (V1: "User Contrast")	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REF (MV)	Affy Accession #	Description
	8				33963_at	azurocidin 1 (cationic antimicrobial protein 37)
	9				32254_at	vesicle-associated membrane protein 2 (synaptobrevin 2)
	13				31888_s_at	tumor suppressing subtransferable candidate 3
	14	26	7		35322_at	Kelch-like ECH-associated protein 1
		2			36970_at	KIAA0182 protein
		3			41097_at	telomeric repeat binding factor 2
		4			37986_at	erythropoietin receptor
		5			40272_at	collapsin response mediator protein 1
		7			35991_at	Sm protein F
		8			38155_at	"origin recognition complex, subunit 5 (yeast homolog)-like"
		9			32624_at	DKFZp566D133 protein
		10			40534_at	"protein tyrosine phosphatase, receptor type, D"
		11			39742_at	TRAF family member-associated NFKB activator
		12			37218_at	"BTG family, member 3"
		14			39552_at	phosphatase and tensin homolog (mutated in multiple advanced cancers 1)
		15	6		36144_at	KIAA0080 protein
		16			41667_s_at	"dTDP-D-glucose 4,6-dehydratase"
		17	4		35614_at	transcription factor-like 5 (basic helix-loop-helix)

SM ANOVA ($V \times$ "User Contrast")	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REE (MV)	Affy Accession #	Description
		18			32227_at	"proteoglycan 1, secretory granule"
		19			41214_at	"ribosomal protein S4, Y- linked"
		20			39212_at	hypothetical protein FLJ11191
		21			39696_at	paternally expressed 10
		22			34194_at	Homo sapiens mRNA; cDNA DKFZp564B076 (from clone DKFZp564B076)
		23			40276_at	"proteasome (prosome, macropain) 26S subunit, non- ATPase, 7 (Mov34 homolog)"
		24			38278_at	modulator recognition factor 1
		25			35362_at	myosin X
			5		38270_at	poly (ADP-ribose) glycohydrolase
			8		39607_at	myotubularin related protein 8
			10	13	33957_at	HCGII-7 protein
			11	5	39932_at	Homo sapiens mRNA; cDNA DKFZp586F2224 (from clone DKFZp586F2224)
			12	4	1923_at	cyclin C
			13		38496_at	ELK4, ETS-domain protein (SRF accessory protein I)
			14	9	37024_at	LPS-induced TNF-alpha factor
			15		404_at	interleukin 4 receptor
			17		39116_at	putative membrane protein
			18		36207_at	SEC14 (S. cerevisiae)-like 1
			19	10	40713_at	nuclear factor of activated T-

SM ANOVA (V1 "User Contrast")	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REE (MV)	Affy Accession #	Description
						cells 5, tonicity-responsive
			20		41795_at	NCK adaptor protein 1
			21		38005_at	nucleotide-sugar transporter similar to C. elegans sqv-7
			22		38779_r_at	hepatoma-derived growth factor (high-mobility group protein 1- like)
			23		41509_at	heat shock 70kD protein 9B (mortalin-2)
			24		37231_at	KIAA0008 gene product
			25		35414_s_at	jagged 1 (Alagille syndrome)
				3	40817_at	nucleobindin 1
				6	37908_at	guanine nucleotide binding protein 11
				7	36342_r_at	H factor (complement)-like 3
				8	38113_at	synaptic nuclei expressed gene 1b
				12	40364_at	solute carrier family 31 (copper transporters), member 1
				14	31407_at	protease, serine, 7 (enterokinase)
				15	39681_at	zinc finger protein 145 (Kruppel-like, expressed in promyelocytic leukemia)
				16	AFFX-BioB- M at	NO_SIF_seq
				17	41620_at	KIAA0716 gene product
				18	31862_at	wingless-type MMTV integration site family, member 5A

SM ANOVA (V ₁ "User Contrast")	XW Rank- Ordering Statistic	XW GA/KNN	HK Stepwise Discriminant Analysis, HK (MV)	EA SVM/REF (MV)	Affy Accession #	Description
				19	39265_at	type 1 tumor necrosis factor receptor shedding aminopeptidase regulator
				20	38866_at	GRB2-related adaptor protein 2
				21	33316_at	KIAA0808 gene product
				22	1881_at	NO_ ₂ SIF_seq
				23	346_s_at	angiotensin receptor 1
				24	39457_r_at	sorting nexin 4
				25	40549_at	cyclin-dependent kinase 5

Table 42
Annotation Tool for Table 40

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
39418_at					AK025446, AK025446, AL049999, All Genbank Accessions		DKFZP564M182 protein		16p13.13 Bottom of Form
	39418_at		DKFZP564M182	26156	AF001862, AF001862, AF116653, AF198052, BC015933, BC017775, BX647195, BX647196, NM_001465 , All Genbank Accessions			[Proteome FUNCTION:] FYN- binding protein; modulates interleukin 2 production	5p13.1 Bottom of Form
41819_at	41819_at		FYB	2533		602731	FYN binding protein (FYB- 120/130)		

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
37981 at	37981_at		DBN1	1627	AI683844, AI683844, AK094125, AL110225, AW950551, BC000283, BC007281, BC007567, BF205663, D17530, NM_004395, NM_080881, All Genbank Accessions	126660	drebrin 1	[SUMMARY:] The protein encoded by this gene is a cytoplasmic actin- binding protein thought to play a role in the process of neuronal growth. It is a member of the drebrin family of proteins that are developmentally regulated in the brain. A decrease in the amount of this protein in the brain has been implicated as a possible contributing factor in the pathogenesis of memory disturbance in Alzheimer's disease. At least two alternative splice variants encoding different protein isoforms have been described for this gene.	5q35.3 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
577_at	577_at		MDK	4192	BC011704, BC011704, D10604, M69148, M94250, NM_002391, X55110 , All Genbank Accessions	1620962	midkine (neurite growth-promoting factor)		11p11.2 Bottom of Form
37343_at	37343_at		ITPR3	3710	D26351, D26351, NM_002224, U01062 , All Genbank Accessions	147267	inositol 1,4,5-trisphosphate receptor, type 3		6p21 Bottom of Form
32058_at	32058_at		CHST10	9486	AF033827, AF033827, AF070594, BC010441 , All Genbank Accessions	60637610	carbohydrate sulfotransferase	[SUMMARY:] Cell surface carbohydrates modulate a variety of cellular functions and are typically synthesized in a stepwise manner. HNK1ST plays a role in the biosynthesis of HNK1 (CD57; MIM 151290), a neuronally expressed carbohydrate that contains a	2q12.1 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
								sulfoglucuronyl residue [supplied by OMIM]	
33412_at	33412_at		LGALS1	3956	AB097036, AB097036, BC001693, BC020675, BT006775, J04456, M57678, NM_002305, S44881, X14829, X15256 , All Genbank Accessions		lectin, galactoside- binding, soluble, 1505701 (galectin 1)	[SUMMARY:] The galectins are a family of beta- galactoside-binding proteins implicated in modulating cell- cell and cell-matrix interactions. LGALS1 may act as an autocrine negative growth factor that regulates cell proliferation.	22q13.1 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
1126_s at	1126_s_		CD44	960	AJ251595, AJ251595, AY101192, AY101193, BC004372, BC052287, L05424, M24915, M25078, M59040, NM_000610, S66400, U40373, X56794, X62739, X66733 , All Genbank Accessions	107269	CD44 antigen (homing function and Indian blood group system)		11p13 Bottom of Form
671 at	671 at		SPARC	6678	AK096969, AK096969, BC004974, BC008011, J03040, NM_003118, Y00755 , All Genbank Accessions	182120	secreted protein, acidic, cysteine- rich (osteonectin)		5q31.3-q32 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
32970_f_at	32970_f_at		HABP4	22927	AF241831, AF241831, AK000610, AK025144, AK055161, NM_014282, All Genbank Accessions		hyaluronan binding protein 4		9q22.3-q31 Bottom of Form
824_at	824_at		GSTO1	9446	AF212303, AF212303, BC000127, D17168, NM_004832, U90313 , All Genbank Accessions	605482	glutathione S- transferase omega 1	[SUMMARY:] This gene encodes a member of the theta class glutathione S- transferase-like (GSTTL) protein family. In mouse, the encoded protein acts as a small stress response protein, likely involved in cellular redox homeostasis.	10q25.1 Bottom of Form
32724_at	32724_at		PHYH	5264	AF023462, AF023462, AF112977, AF242379, BC021011, BC029512, NM_006214 , All Genbank Accessions	602026	phytanoyl-CoA hydroxylase (Refsum disease)	[SUMMARY:] The protein encoded by this gene is a peroxisomal enzyme. It catalyzes the initial alpha-oxidation step in the degradation of phytanic acid and	10pter-p11.2 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
								converts phytanoyl-CoA to 2-hydroxyphytanoyl-CoA. It interacts specifically with the immunophilin FKBP52. Refsum disease, an autosomal recessive neurologic disorder, is caused by the deficiency of this encoded protein.	
38652_at	38652_at		FLJ20154	54838	AF070644, AF070644, AK000161, AK000374, AK056285, BC010506, NM_017690 , All Genbank Accessions		hypothetical protein FLJ20154		10q24.33 Bottom of Form
36331_at	36331_at		TMEM1	7109	NM_003274, NM_003274, U19252, U61500, U61520 , All Genbank Accessions	602103	transmembrane protein 1		21q22.3 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
							Homo sapiens cDNA FLJ30991 fis, clone HLUNG1000041 Bottom of Form		
41478 at	41478 at							[SUMMARY:] Glycophorin C (GYPC) is an integral membrane glycoprotein. It is a minor species carried by human erythrocytes, but plays an important role in regulating the mechanical stability of red cells. A number of glycophorin C mutations have been described. The Gerbich and Yus phenotypes are due to deletion of exon 3 and 2, respectively. The Webb and Duch antigens, also known as	2q14-q21 Bottom of Form
38119 at	38119 at		GYPC	2995	BC016653, BC016653, M11802, M28335, M29662, M36284, NM_002101, NM_016815, X12496, X13890, X14242, X51973 , All Genbank Accessions	110750	glycophorin C (Gerbich blood group)		

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
								glycophorin D, result from single point mutations of the glycophorin C gene. The glycophorin C protein has very little homology with glycophorins A and B.	
36927_at	36927_at		C1orf29	10964	AB000115, AB000115, AL832618, BC015932 , All Genbank Accessions		chromosome 1 open reading frame 29	[Proteome FUNCTION:] Moderately similar to MTAP44	1p31.1 Bottom of Form
35145_at	35145_at		MNT	4335	NM_020310, NM_020310, X96401, Y13440, Y13444 , All Genbank Accessions	603039	MAX binding protein		17p13.3 Bottom of Form

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
33637_g at _at	33637_g				AF038567, AF038567, AF277315, AJ003149, AJ275977, AJ275978, NM_001327 , All Genbank Accessions				Xq28 Bottom of Form
			CTAG1	1485		300156	cancer/testis antigen 1	[Proteome FUNCTION:] Cancer-testis antigen	
34610 at	34610 at				AK095666, AK095666, BC000214, BC000366, BC010119, BC014256, BC014788, BC017287, BC019093, BC019362, BC021993, BC029996, BC032006, BC035460, M24194, NM_006098 , All Genbank Accessions				5q35.3 Bottom of Form
			GNB2L1	10399		176981	guanine nucleotide binding protein (G protein), beta polypeptide 2- like 1		

	AFFYID	VALUE	SYMBOL	LOCUS LINK	GENBANK	OMIM	GENE NAME	SUMMARY	Map Location
35659 at	35659 at		IL10RA		BC028082, BC028082, BM193545, NM_001558, U00672 , All Genbank Accessions	146933	interleukin 10 receptor, alpha	[SUMMARY:] The protein encoded by this gene is a receptor for interleukin 10. This protein is structurally related to interferon receptors. It has been shown to mediate the immunosuppressive signal of interleukin 10, and thus inhibits the synthesis of proinflammatory cytokines. This receptor is reported to promote survival of progenitor myeloid cells through the insulin receptor substrate-2/PI 3-kinase/AKT pathway. Activation of this receptor leads to tyrosine phosphorylation of JAK1 and TYK2 kinases.	11q23

EXAMPLE XII

Gene Expression Profiling of Pediatric Acute Lymphoblastic Leukemia Reveals Unique Subgroups Not Predicted by Current Genetic Risk Stratification

5

Summary

Current ALL classification schemes mask inherent biologic predictors of outcome. Classification schemes that reflect the underlying biology of this disease could guide patients to more tailored treatments. To develop gene expression-based classification schemes related to the pathogenic basis of pediatric lymphoblastic leukemia, gene expression patterns observed in the statistically designed cohort containing 254 pediatric acute lymphoid leukemia (ALL) cases described in Example 10 IA were examined using Affymetrix U95AV2 oligonucleotide microarrays. Additionally, in order to model remission vs. failure conditioned to predictive cytogenetics, matched patients were selected among all major genetic prognostic 15 groups (*MLL/AF4*, *BCR/ABL*, *E2A/PBX1*, *TEL/AML1*, hyperdiploidy, and hypodiploidy).

The data were analyzed for class discovery using unsupervised clustering methods (hierarchical clustering and a force directed algorithm) and for class 20 prediction using supervised learning techniques including Bayesian Nets, Fisher's Discriminant, and Support Vector Machines. During initial exploratory data analysis, several distinct clusters were observed using unsupervised clustering methods. Interestingly, no correlation between the currently employed risk classification groups and these clusters was evident. In particular, ALL cases characterized by accepted 25 "good" and "poor" risk genetics were distributed differentially among the identified clusters. This class discovery analysis indicates a more complex intrinsic genetic and biologic background in pediatric ALL than currently appreciated.

Gene expression profiles associated with achievement of remission vs. treatment failure were then sought using supervised learning techniques. Derived 30 predictive algorithms were applied to a training set of the data. Their performance was evaluated with multiple cross validation and bootstrap runs, with an average accuracy of 72% and low variance. These models are being tested on the validation set. The results provide evidence of additional heterogeneity of pediatric ALL, which may relate to novel transformation pathways and clinical outcomes.

Data Analysis

The analysis of the gene expression data was done in a two-step approach. First, in order to identify potential clusters and inherent biologic groups, a large number of clinical co-variables were correlated with the expression data using unsupervised clustering methods such as hierarchical clustering, principal component analysis and a force-directed clustering algorithm coupled with a novel visualization tool (*VxInsight*). For class prediction, supervised learning methods such as Bayesian Networks, Support Vector Machines with Recursive Feature Elimination (SVM-RFE), Neuro-Fuzzy Logic and Discriminant Analysis were employed to create classification algorithms. The performance of these classification algorithms was evaluated using fold-dependent leave-one-out cross validation (LOOCV) techniques. These methods combined allowed the identification of genes associated with remission or treatment failure and with the different translocations across the dataset.

Results

To explore potential clusters driven by gene expression profiles, the initial analysis of the pediatric ALL cohort was accomplished using a force directed clustering algorithm coupled with a novel visualization tool, *VxInsight* as described in Example IB. Unexpectedly, we discovered 9 novel biologic clusters of ALL (2 distinct T-cell ALL clusters (S1 and S2) and 7 (2 related clusters are seen in cluster X) distinct B-lineage ALL clusters (A, B, C, X, Y, Z)) each with distinguishing gene expression profiles. Using ANOVA, we identified over 100 statistically significant genes uniquely distinguishing each of these cohorts; a list of the top statistically significant genes distinguishing each cluster is provided in Table 43. Review of these lists of genes reveals many interesting signaling molecules and transcription factors. The X cluster (which contains two highly related clusters) is quite unique in having expression of several genes regulating methylation and folate metabolism.

Examination of the cluster data reveals that while there are some trends, no cytogenetic abnormality precisely defines or is correlated with any specific cluster. It is interesting that cases with a t(12;21) or hyperdiploidy, both conferring low risk and good outcomes, tend to cluster together; although combinations of these cases can be seen primarily in clusters C and Z as well as the top component of the X cluster indicating that there is still heterogeneity in gene expression profiles associated with

these clusters. On the terrain map from VxInsight (Fig. 6, top) these three cluster regions (C, Z, and X) are actually fairly closely approximated indicating they are more related than for example cluster C to cluster S2. Although our correlations between outcome and clusters are still underway, it is interesting that the hyperdiploid and t(12;21) cases in cluster X had a significantly poorer outcome than those in cluster C or Z, suggesting that these cluster groupings may reflect different biologic propensities that confer differing responses to therapy. Similarly, the t(1;19) cases clustered in Y had a poorer outcome than those in clusters A and B. Finally, it is of interest that ALL cases with t(9;22) simply don't cluster, they appear to be distributed among virtually all B precursor clusters. While we do not understand the significance of this result, it suggests that the t(9;22) is a pre-leukemic or initiating genetic lesion that may not be sufficient for leukemogenesis, or alternatively, that clones with a t(9;22) are quite genetically unstable and transformation and genetic progression may occur along many pathways. Results similar to our own were recently reported by Fine et al. (Blood Abstract, Blood Supplement 2002 (753a, Abstract #2979)). Using hierarchical clustering on a small series of 35 cell lines and ALL cases, these investigators found a limited correlation between intrinsic biologic clusters in ALL and cytogenetic abnormalities; cases with a t(9;22) were found to be particularly heterogeneous in their gene expression profiles.

The stability and structure of the clusters was explored using methods of data perturbation. Because the clusters appeared to be steady, subsequent exploration of the group-characterizing genes was performed using analysis of variance (ANOVA). This method was applied to order all of the genes with respect to differential expressions between the groups. The strongest 0.1% of the genes were tabulated in lists. The strength of these gene lists was studied using statistical bootstrapping as described in Example IB, and suggested that the identified groups represented well-separated patient subclasses.

Surprisingly, with the exception of the T-ALL cases (clusters S₁ and S₂), the clustering of ALL patients was independent of karyotype, suggesting that common tumor genetics, as currently applied to prognostic schema, do not strongly influence or drive innate expression profiling in pediatric ALL. However, fewer "adverse prognosis" genetics were distributed among certain clusters (e.g. C and Z).

Remarkably, patients with translocations such as t(9;22)/*BCR-ABL*, t(1;19)/*E2A/PBX1*, and t(12;21)/*TEL/AML1*, were distributed among several clusters,

suggesting biologic heterogeneity beyond the present tendency to group these various entities for the purpose of prognosis and outcome prediction. The results of these class discovery methods suggested that, when applied to our patient data set, unsupervised techniques elucidate underlying novel subgroups pediatric ALL. In turn, this
5 reassessment of tumor heterogeneity encourages the design of additional studies to ascertain whether these data can enhance the discriminatory power of currently employed prognostic variables.

Analysis was therefore next focused on class prediction. The process of defining the best set of discriminating genes between known subsets of samples can
10 be accomplished using supervised learning techniques such as Bayesian Networks, linear discriminant analysis and support vector machines (SVM). In contrast to unsupervised methods that generate inherent "classes" for each gene or patient, supervised learning methods are trained to recognize "known classes", creating classification algorithms that may also uncover interesting and novel therapeutic
15 targets.

Genes that best discriminated T-lineage ALL from B-lineage ALL were identified using principal component analysis and ANOVA of the cluster-differentiating genes generated from the *VxInsight* analysis. Significant overlap was observed between the 2 methods used in our analysis of the T-cell ALL gene
20 expression profile, as well as with published data (Yeoh et al., Cancer Cell 1; 133-143, 2002), both in the actual presence of the same genes, as well as in relative rank (Fig. 7). Importantly, this is evident across data sets and regardless of analytic approach for T-cell ALL, suggesting that these genes define important features of T-ALL biology. It also implies that T-ALL gene expression is inherently "less
25 complex" in delineating this leukemic entity, than for B-lineage ALL.

Gene expression profiles characteristic of translocation types were derived using supervised learning techniques. 147 genes derived from Bayesian network analysis that allowed the identification of samples within each of the major translocation groups with accuracy rates higher than 90%, as calculated by fold
30 dependent leave-one-out cross validation. This filtered data analysis of gene expression conditioned on karyotype generated distinct case clustering, confirming that unique gene expression "signatures" identify defined genetic subsets of ALL. This corroborates recently published data (Yeoh et al., Cancer Cell 1; 133-143, 2002) which revealed that karyotypic sub-groups of ALL are characterized by specific gene

expression profiles (Fig. 8). Unsupervised methods do not clearly identify clusters of patients by therapeutic outcome. Nonetheless, some clusters (e.g. C, Y, S1) contain a greater number of remission cases. When the clusters are examined for remission versus failure by karyotype, it is evident that there is only minimal correlation

5 between the distribution of prognostically important tumor genetics and outcome. For example, while clusters C and Z have similar distributions of case number and karyotypic sub-types, more C group patients achieved remission. Cluster Y, which harbors a greater proportion of adverse prognosis genetic types, unexpectedly demonstrates a relatively high percentage of remission cases. These findings imply
10 that the biology of clinical outcome in pediatric ALL is more complex than previously appreciated and is not readily determined by the relatively gross examination of tumor cytogenetics. These data thus support the observation that relapse in pediatric ALL occurs regardless of NCI clinical risk category, or current genetic risk modifiers. It is notable that gene expression analysis identifies 2 sub-populations of T-ALL, one of
15 which (S1) demonstrates a favorable therapeutic outcome.

Comparison with method and results of Yeoh et al. (Cancer Cell 1; 133-143, 2002)

Yeoh et al., in a study performed on the "Downing" or "St. Jude" data set as described above, reported that pediatric ALL cases clustered according to the
20 recurrent cytogenetic abnormalities associated with ALL, and thus, that cytogenetics could define these intrinsic groups. However, careful reading of this report and the methods of analysis employed reveals that these investigators did not perform and/or report the results of true *unsupervised* learning methods and class discovery. Rather, these investigators first used supervised learning algorithms (primarily Support
25 Vector Machines) to identify short lists of expressed genes that were associated with each recurrent cytogenetic abnormality in ALL. Using a highly selected set of only 271 genes that resulted from this supervised learning approach, they then performed hierarchical clustering or PCA using the expression data derived from only this set of selected genes. As would be expected from this approach, distinct ALL clusters could
30 be defined based on shared gene expression profiles and each cluster was associated with a specific cytogenetic abnormality. However, this approach did not reveal what the underlying structure was in the gene expression profiles if one took a truly unbiased approach and performed real class discovery.

Furthermore, although Yeoh et al. attempted to use supervised learning methods to identify genes associated with outcome, they were not successful. Potential outcome genes identified in training sets could not be confirmed in independent test sets, indicating that the learning algorithms employed were "over-fitting" the data - a not uncommon problem with supervised learning algorithms. Another potential problem with these studies was that was no statistical design for the cases selected for study in this St. Jude cohort; cases were selected simply based on sample availability. Thus, in contrast to our retrospective POG cohort design in which cases with long term remission were balanced roughly 50:50 with cases that failed, the St. Jude cases were predominantly cases with long term remission (>80%), making the modeling in the St. Jude dataset far more difficult. We have come to appreciate is how important statistical design and case selection is to any array study (indeed for any scientific study) and that for supervised learning algorithms and class prediction, it is very important to have the label that one is trying to predict (such as outcome or the presence of a particular genetic abnormality) balanced 50:50 in the cohort undergoing modeling and within the training and test sets.

TABLE 43

GENES THAT DISTINGUISH BETWEEN THE VxINSIGHT CLUSTERS (BY ANOVA)
IN THE PEDIATRIC ALL MICROARRAY COHORT

CLUSTER A	PROBE	TITLE – CLUSTER A	GENE SYMBOL	LOCATION
10	37188_at	phosphoenolpyruvate carboxykinase 2 (mitochondrial)	PCK2	14q11.2
	33342_at	RNA, U transporter 1	RNUT1	15q22.33
	35701_at	v-Ha-ras Harvey rat sarcoma viral oncogene homolog	HRAS	11p15.5
	36193_at	partner of RAC1 (arfaptin 2)	POR1	11p15
	40084_at	transcription factor CP2	TFCP2	12q13
15	38895_i_at	neutrophil cytosolic factor 4 (40kD)	NCF4	22q13.1
	39780_at	protein phosphatase 3 (formerly 2B), catalytic subunit, beta isoform	PPP3CB	10q21-q22
	33430_at	DKFZP586M1523 protein	DKFZP586M1523	18q12.1
	35911_r_at	matrix metalloproteinase-like 1	MMPL1	16p13.3
	34255_at	diacylglycerol O-acyltransferase homolog 1 (mouse)	DGAT1	8qter
20	39009_at	Lsm3 protein	LSM3	3p25.1
	1382_at	replication protein A1 (70kD)	RPA1	17p13.3
	35695_at	Chediak-Higashi syndrome 1	CHS1	1q42.1-q42.2
	40676_at	integrin beta 3 binding protein (beta3-endonexin)	ITGB3BP	1p31.3
	40472_at	Homo sapiens clone 23763 unknown mRNA, partial cds	no gene symbol	no location
25	37479_at	CD72 antigen	CD72	9p11.2
	41198_at	granulin	GRN	17q21.32
	40486_g_at	DIPB protein	HSA249128	11p11.2
	41057_at	uncharacterized hypothalamus protein HT012	HT012	6p21.32
	34359_at	CGI-130 protein	LOC51020	6q13-q24.3
30	37303_at	ADP-ribosyltransferase (NAD ⁺ ; poly polymerase)-like 1	ADPRTL1	13q11
	36626_at	hydroxysteroid (17-beta) dehydrogenase 4	HSD17B4	5q21
	36276_at	contactin 2 (axonal)	CNTN2	1q32.1
	41308_at	C-terminal binding protein 1	CTBP1	4p16
	39965_at	ras-related C3 botulinum toxin substrate 3	RAC3	17q25.3
35	40487_at	DIPB protein	HSA249128	11p11.2
	39043_at	actin related protein 2/3 complex, subunit 1B (41 kD)	ARPC1B	7q11.21
	467_at	osteoclast stimulating factor 1	OSTF1	12q24.1-24.2
	37898_r_at	Homo sapiens, clone MGC:22588 IMAGE:4696566, complete cds	no gene symbol	no location

38104	at	2,4-dienoyl CoA reductase 1, mitochondrial	DECRI	8q21.3
36091	at	src family associated phosphoprotein 2	SCAP2	7p21-p15
399	at	serine/threonine kinase 25 (STE20 homolog, yeast)	STK25	2q37.3
34970	r_at	5-oxoprolinase (ATP-hydrolysing)	OPLAH	8
39743	at	hypothetical protein FLJ20580	FLJ20580	1p33
35843	at	NIMA (never in mitosis gene a)-related kinase 9	NEK9	14q24.2
1250	at	protein kinase, DNA-activated, catalytic polypeptide	PRKDC	8q11
33250	at	chromosome 6 open reading frame 11	C6orf11	6p21.3
32245	at	KIAA0737 gene product	KIAA0737	14q11.1
37845	at	hematopoietic protein 1	HEM1	12q13.1
1599	at	cyclin-dependent kinase inhibitor 3	CDKN3	14q22
33727	r_at	tumor necrosis factor receptor superfamily, member 6b, decoy	TNFRSF6B	20q13.3
35820	at	GM2 ganglioside activator protein	GM2A	5q31.3-q33.1
39896	at	DEAD/H (Asp-Glu-Ala-Asp/His) box polypeptide 16	DDX16	6p21.3
40509	at	electron-transfer-flavoprotein, alpha polypeptide (aciduria II)	ETFA	15q23-q25
35986	at	histone acetyltransferase MYST1	MYST1	16p11.1
34765	at	KIAA0020 gene product	KIAA0020	9p24.2
40063	at	nuclear domain 10 protein	NDP52	17q23.2
40415	at	acetyl-Coenzyme A acyltransferase 1	ACAA1	3p23-p22
1553	r_at	no title	no gene symbol	no location
37251	s_at	glycoprotein M6B	GPM6B	Xp22.2
567	s_at	promyelocytic leukemia	PML	15q22
1804	at	kallikrein 3, (prostate specific antigen)	KLK3	19q13.41
1280	i_at	no title	no gene symbol	no location
32701	at	armadillo repeat gene deletes in velocardiofacial syndrome	ARVCF	22q11.21
39779	at	TAR (HIV) RNA binding protein 1	TARBP1	1q42.3
40323	at	CD38 antigen (p45)	CD38	4p15
41058	g_at	uncharacterized hypothalamus protein HT012	HT012	6p21.32
38990	at	F-box only protein 9	FBXO9	6p12.3-p11.2
40133	s_at	glyoxylate reductase/hydroxypyruvate reductase	GRHPR	9q12
33350	s_at	JM5 protein	JM5	Xp11.23
1238	at	mitogen-activated protein kinase 9	MAPK9	5q35
40982	at	hypothetical protein FLJ10534	FLJ10534	17p13.3
32866	at	KIAA0605 gene product	KIAA0605	9q34.3
38571	at	FGFR1 oncogene partner	FOP	6q27
37955	at	transmembrane protein 4	TMEM4	12q15
41799	at	DnaI (Hsp40) homolog, subfamily C, member 7	DNAJC7	17q11.2
33493	at	erythroid differentiation and denucleation factor 1	HFL-EDDG1	18p11.1

38242_at	B-cell linker	BLNK	10q23.2-q23.33
34894_r_at	protease, serine, 22	PRSS22	16p13.3
41322_s_at	nucleolar protein family A, member 2	NOLA2	5q35.3
37885_at	hypothetical protein AF038169	AF038169	2q22.1
32789_at	nuclear cap binding protein subunit 2, 20kD	NCBP2	3q29
34294_at	kinesin family member C3	KIFC3	16q13-q21
1827_s_at	v-myc myelocytomatosis viral oncogene homolog (avian)	MYC	8q24.12-q24.13
37905_r_at	no title	no gene symbol	no location
33323_r_at	stratiferin	SFN	1p35.3
33126_at	glycosyltransferase AD-017	AD-017	3p21.31
32484_at	chemokine binding protein 2	CCBP2	3p21.3
37392_at	phosphorylase kinase, beta	PHKB	16q12-q13
396_f_at	erythropoietin receptor	EPOR	19p13.3-p13.2
40789_at	adenylate kinase 2	AK2	1p34
34573_at	ephrin-A3	EFNA3	1q21-q22
1008_f_at	protein kinase, interferon-inducible double stranded RNA dependent	PRKR	2p22-p21
721_g_at	heat shock transcription factor 4	HSF4	16q21
948_s_at	peptidylprolyl isomerase D (cyclophilin D)	PPID	4q31.3
38640_at	zinc finger protein	LOC51042	1p35.3
36907_at	mevalonate kinase (mevalonic aciduria)	MVK	12q24
32220_at	high-mobility group (nonhistone chromosomal) protein 1	HMG1	13q12
41184_s_at	proteasome (prosome, macropain) subunit, beta type, 8	PSMB8	6p21.3

CLUSTER B

25	PROBE	TITLE -CLUSTER B	GENE SYMBOL	LOCATION
32854_at	F-box and WD-40 domain protein 1B	FBXW1B	5q35.1	
39224_at	centaurin, delta 1	CENTD1	4p15.1	
41625_at	thyroid hormone receptor-associated protein, 240 kDa subunit	TRAP240	17q22-q23	
35289_at	rab6 GTPase activating protein (GAP and centrosome-associated)	GAPCENA	9q34.11	
38082_at	KIAA0650 protein	KIAA0650	18p11.31	
35268_at	axotrophin	AXOT	2q24.2	
36827_at	golgi phosphoprotein 1	GOLPH1	1q41	
39759_at	homolog of mouse quaking QKI (KH domain RNA binding protein)	QKI	6q26-27	
34879_at	dolichyl-phosphate mannosyltransferase polypeptide 1, catalytic	DPM1	20q13.13	
38462_at	NADH dehydrogenase (ubiquinone) 1 alpha subcomplex,5	NDUFA5	7q32	
38659_at	soc-2 suppressor of clear homolog (C. elegans)	SHOC2	10q25	
38837_at	hypothetical protein DJ971N18.2	DJ971N18.2	20p12	
36144_at	KIAA0080 protein	KIAA0080	1	

5	37731_at	epidermal growth factor receptor pathway substrate 15	EPS15	1p32
	38685_at	syntaxin 12	STX12	1p35-34.1
	38765_at	Dicer1, Dcr-1 homolog (Drosophila)	DICER1	14q32.2
	38056_at	KIAA0195 gene product	KIAA0195	17
	38764_at	Homo sapiens clone 23938 mRNA sequence	no gene symbol	no location
10	41651_at	KIAA1033 protein	KIAA1033	12q24.11
	38041_at	UDP-N-acetyl-alpha-D-galactosamine:polypeptide N-acetyl/galactosaminyltransferase 1 (GalNAc-T1)	GALNT1	18q12.1
	34654_at	myotubularin related protein 1	MTMR1	Xq28
	1814_at	transforming growth factor, beta receptor II (70-80kD)	TGFBR2	3p22
	34370_at	archain 1	ARCN1	11q23.3
15	36474_at	KIAA0776 protein	KIAA0776	6q16.3
	33805_at	centrosome-associated protein 350	CAP350	1p36.13-q41
	33418_at	RAB3 GTPase-ACTIVATING PROTEIN	RAB3GAP	2q14.3
	35279_at	Tax1 (human T-cell leukemia virus type I) binding protein 1	TAX1BP1	7p15
	34800_at	ortholog of mouse integral membrane glycoprotein LIG-1	LIG1	no location
20	34825_at	TRAF and TNF receptor-associated protein	AD022	6p22.1-22.3
	39389_at	CD9 antigen (p24)	CD9	12p13.3
	39964_at	retinitis pigmentosa 2 (X-linked recessive)	RP2	Xp11.4-p11.21
	40610_at	zinc finger RNA binding protein	ZFR	5p13.2
	706_at	no title	no gene symbol	no location
25	33761_s_at	KIAA0493 protein	KIAA0493	1q21.3
	35793_at	Ras-GTPase activating protein SH3 domain-binding protein 2	G3BP2	4q21.1
	33893_r_at	KIAA0470 gene product	KIAA0470	1q44
	35258_f_at	splicing factor, arginine/serine-rich 2, interacting protein	SFRS2IP	12p11.21
	40839_at	ubiquitin-like 3	UBL3	13q12-q13
30	32857_at	son of sevenless homolog 2 (Drosophila)	SOS2	14q21
	40591_at	cell division cycle 27	CDC27	17q12-17q23.2
	33381_at	nuclear receptor coactivator 3	NCOA3	20q12
	35205_at	cofactor of BRCA1	COBRA1	no location
	32872_at	Homo sapiens mRNA; cDNA DKFZp564I083	no gene symbol	no location
35	39695_at	decay accelerating factor for complement (CD55)	DAF	1q32
	39691_at	SH3-domain GRB2-like endophilin B1	SH3GLB1	1p22
	35153_at	Nijmegen breakage syndrome 1 (nibrin)	NBS1	8q21-q24
	38818_at	serine palmitoyltransferase, long chain base subunit 1	SPTLC1	9q21-q22
	34877_at	Janus kinase 1 (a protein tyrosine kinase)	JAK1	1p32.3-p31.3
	33879_at	sigma receptor (SR31747 binding protein 1)	SR-BP1	9p11.2
	37685_at	phosphatidylinositol binding clathrin assembly protein	PICALM	11q14

5	40865_at	thymine-DNA glycosylase	TDG	12q24.1
	35847_at	ubiquitin specific protease 24	USP24	1p32.2
	38505_at	Homo sapiens mRNA; cDNA DKFZp586J0720	no gene symbol	no location
	35973_at	Huntingtin interacting protein H	HYPH	12q21.1
	37683_at	ubiquitin specific protease 10	USP10	16q24.1
10	40901_at	nuclear autoantigen	GS2NA	14q13-q21
	39745_at	optic atrophy 1 (autosomal dominant)	OPA1	3q28-q29
	41360_at	CCR4-NOT transcription complex, subunit 8	CNOT8	5q31-q33
	36002_at	KIAA1012 protein	KIAA1012	18q11.2
	37537_at	ADP-ribosylation factor domain protein 1, 64kD	ARFD1	5q12.3
15	40438_at	protein phosphatase 1, regulatory (inhibitor) subunit 12A	PPP1R12A	12q15-q21
	34394_at	activity-dependent neuroprotector	ADNP	20q13.13-q13.2
	34312_at	nuclear receptor coactivator 2	NCOA2	8q13.1
	1827_s_at	v-myc myelocytomatosis viral oncogene homolog (avian)	MYC	8q24.12-q24.13
	32336_at	aldolase A, fructose-bisphosphate	ALDOA	16q22-q24
20	34349_at	SEC63 protein	SEC63L	6q21
	37828_at	hypothetical protein FLJ11220	FLJ11220	1p11.2
	36579_at	ubiquitination factor E4A (UFD2 homolog, yeast)	UBE4A	11q23.3
	39140_at	hypothetical protein	LOC54505	5q11.2
	39965_at	ras-related C3 botulinum toxin substrate 3 (rho family)	RAC3	17q25.3
25	38115_at	lung cancer candidate	FUS1	3p21.3
	41457_at	KIAA0423 protein	KIAA0423	14q21.1
	41634_at	KIAA0256 gene product	KIAA0256	15q15.1
	32172_at	SMART/HDAC1 associated repressor protein	SHARP	1p36.33-p36.11
	40801_at	DKFZP434C212 protein	DKFZP434C212	9q34.11
30	40138_at	COP9 subunit 6 (MOV34 homolog, 34 kD)	MOV34-34KD	7q11.1
	35734_at	ARP2 actin-related protein 2 homolog (yeast)	ACTR2	2p14
	33727_r_at	tumor necrosis factor receptor superfamily, member 6b, decoy	TNFRSF6B	20q13.3
	39099_at	Sec23 homolog A (S. cerevisiae)	SEC23A	14q13.2
	35747_at	stromal cell derived factor receptor 1	SDFR1	15q22
35	37575_at	Homo sapiens mRNA; cDNA DKFZp586C1723	no gene symbol	no location
	38443_at	hypothetical protein MGC14433	MGC14433	12q24.11
	35199_at	KIAA0982 protein	KIAA0982	10p15.3
	969_s_at	ubiquitin specific protease 9, X chromosome (Drosophila)	USP9X	Xp11.4
	41601_at	tumor necrosis factor, alpha, converting enzyme	ADAM17	2p25
	34329_at	p21 (CDKN1A)-activated kinase 2	PAK2	3
	33831_at	CREB binding protein (Rubinstein-Taybi syndrome)	CREBBP	16p13.3
	35295_g_at	Sjogren syndrome antigen A2 (60kD, SS-A/Ro)	SSA2	1q31

40613_at	beta-site APP-cleaving enzyme	BACE	11q23.2-q23.3
CLUSTER C			
5	PROBE	TITLE - CLUSTER C	LOCATION
5	840_at	zinc finger protein 220	8p11
	1463_at	protein tyrosine phosphatase, non-receptor type 12	7q11.23
	35739_at	myotubularin related protein 3	22q12.2
	39809_at	HMG-box containing protein 1	7q31.1
	40140_at	zinc finger protein 103 homolog (mouse)	2p11.2
10	37497_at	hematopoietically expressed homeobox	10q24.1
	38148_at	cryptochrome 1 (photolyase-like)	12q23-q24.1
	33861_at	CCR4-NOT transcription complex, subunit 2	12q13.2
	40570_at	forkhead box O1A (rhabdomyosarcoma)	13q14.1
	39696_at	paternally expressed 10	7q21
15	33392_at	DKFZP434J154 protein	7p22.3
	40128_at	KIAA0171 gene product	5q23.1-q33.3
	34892_at	tumor necrosis factor receptor superfamily, member 10b	8p22-p21
	1039_s_at	hypoxia-inducible factor 1, alpha subunit (basic helix-loop-helix transcription factor)	H1F1A
	36949_at	casein kinase 1, delta	14q21-q24
20	38278_at	modulator recognition factor 1	17q25
	35338_at	paired basic amino acid cleaving enzyme (furin, membrane associated receptor protein)	2q11.1
	34740_at	forkhead box O3A	PACE
	36942_at	KIAA0174 gene product	6q21
	41577_at	protein phosphatase 1, regulatory (inhibitor) subunit 16B	16q23.1
25	32025_at	transcription factor 7-like 2 (T-cell specific, HMG-box)	20q11.23
	38666_at	pleckstrin homology, Sec7 and coiled/coiled domains 1 (cytohesin 1)	10q25.3
	32916_at	protein tyrosine phosphatase, receptor type, E	17q25
	1556_at	RNA binding motif protein 5	10q26
	36978_at	KIAA0077 protein	3p21.3
30	35321_at	tousled-like kinase 2	2p16.2
	38980_at	mitogen-activated protein kinase kinase kinase 7 interacting protein 2	17q23
	1377_at	nuclear factor of kappa light polypeptide gene enhancer in B-cells 1	6q25.1-q25.3
	41409_at	basement membrane-induced gene	4q24
	40841_at	transforming, acidic coiled-coil containing protein 1	1p35.3
35	36150_at	KIAA0842 protein	8p11
	31895_at	BTB and CNC homology 1, basic leucine zipper transcription factor	1p36.13
	1150_at	no title	21q22.11
	32160_at	seven in absentia homolog 1 (Drosophila)	no location
			16q12

31936_s_at	limkain b1	LKAP	16p13.2
37718_at	KIAA0096 protein	KIAA0096	3p24.3-p22.1
40839_at	ubiquitin-like 3	UBL3	13q12-q13
493_at	casein kinase 1, delta	CSNK1D	17q25
5	1519_at	v-ets erythroblastosis virus E26 oncogene homolog 2 (avian)	21q22.2
36845_at	KIAA0136 protein	KIAA0136	21q22.13
39231_at	chromodomain helicase DNA binding protein 1	CHDI	5q15-q21
2035_s_at	enolase 1, (alpha)	ENO1	1p36.3-p36.2
39897_at	KIAA1966 protein	KIAA1966	4q13.1
32804_at	RNA binding motif protein 5	RBM5	3p21.3
34369_at	mitofusin 2	MFN2	1p36.21
37280_at	MAD, mothers against decapentaplegic homolog 1 (Drosophila)	MADH1	4q28
41836_at	calcium homeostasis endoplasmic reticulum protein	CHERP	19p13.1
32544_s_at	Ras suppressor protein 1	RSU1	10p12.31
33304_at	interferon stimulated gene (20kD)	ISG20	15q26
37539_at	RaIGDS-like gene	RGL	1q24.3
32069_at	Nedd4 binding protein 1	N4BP1	16q12.1
38438_at	nuclear factor of kappa light polypeptide gene enhancer in B-cells 1	NFKB1	4q24
34274_at	KIAA1116 protein	KIAA1116	6q25.1-q25.3
32977_at	chromosome 6 open reading frame 32	C6orf32	6p22.3-p21.32
40130_at	follistatin-like 1	FSTL1	3q13.33
954_s_at	no title	no gene symbol	no location
1113_at	bone morphogenetic protein 2	BMP2	20p12
40215_at	UDP-glucose ceramide glucosyltransferase	UGCG	9q31
36115_at	CDC-like kinase 3	CLK3	15q24
35163_at	KIAA1041 protein	KIAA1041	1pter-q31.3
38810_at	histone deacetylase 5	HDAC5	17q21
35260_at	Mlx interactor	MONDOA	12q21.31
39839_at	cold shock domain protein A	CSDA	12p13.1
38372_at	Homo sapiens unknown mRNA	no gene symbol	no location
1512_at	dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 1A	DYRK1A	21q22.13
38767_at	sprouty homolog 1, antagonist of FGF signaling (Drosophila)	SPRY1	4q26
37970_at	mitogen-activated protein kinase 8 interacting protein 3	MAPK8IP3	16p13.3
41814_at	fucosidase, alpha-L-1, tissue	FUCA1	1p34
41532_at	zinc finger protein 151 (pHZ-67)	ZNF151	1p36.2-p36.1
37585_at	small nuclear ribonucleoprotein polypeptide A'	SNRPA1	22q
39692_at	hypothetical protein DKFZp586F2423	DKFZp586F2423	7q34
34745_at	Homo sapiens clone 24473 mRNA sequence	no gene symbol	no location

35760_at	ATP synthase, H ⁺ transporting, mitochondrial F0 complex	ATP5H	12q13
32751_at	interleukin enhancer binding factor 3, 90kD	ILF3	19p13
307_at	arachidonate 5-lipoxygenase	ALOX5	10q11.2
38911_at	nucleoporin 98kD	NUP98	11p15.5
5	41464_at KIAA0339 gene product	KIAA0339	16
34773_at	tubulin-specific chaperone a	TBCA	5q13.2
1325_at	MAD, mothers against decapentaplegic homolog 1 (Drosophila)	MADH1	4q28
33873_at	transcription factor-like 1	TCFL1	1q21
32051_at	hypothetical protein MGC2840 similar to glucosyltransferase	MGC2840	11pter-p15.5
10	34883_at ring finger protein 10	RNF10	12q24.23
37609_at	nucleotide binding protein 1 (MinD homolog, E. coli)	NUBP1	16p12.3
38095_i_at	major histocompatibility complex, class II, DP beta 1	HLA-DPB1	6p21.3
40437_at	DKFZP564G2022 protein	DKFZP564G2022	15q14
36946_at	dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 1A	DYRK1A	21q22.13
15	38208_at solute carrier family 35 (UDP-N-acetylglucosamine (UDP-GlcNAc))	SLC35A3	1p21
755_at	inositol 1,4,5-trisphosphate receptor, type 1	ITPR1	3p26-p25
40898_at	sequestosome 1	SQSTM1	5q35

CLUSTER X

20	PROBE	TITLE - CLUSTER X	GENE SYMBOL	LOCATION
	36553_at	acetylserotonin O-methyltransferase-like	ASMTL	Xp22.3
	35869_at	MD-1, RP105-associated	MD-1	6p24.1
	38287_at	proteasome (prosome, macropain) subunit, beta type, 9	PSMB9	6p21.3
25	38413_at	defender against cell death 1	DADI	14q11-q12
	37311_at	transaldolase 1	TALDO1	11p15.5-p15.4
	41213_at	peroxiredoxin 1	PRDX1	1p34.1
	38780_at	aldo-keto reductase family 1, member A1 (aldehyde reductase)	AKR1A1	1p33-p32
	674_g_at	methylenetetrahydrofolate dehydrogenase (NADP+ dependent), methenyltetrahydrofolate cyclohydrolase, formyltetrahydrofolate synthetase		
30	38824_at	HIV-1 Tat interactive protein 2, 30 kD	MTHFD1	14q24
	32715_at	vesicle-associated membrane protein 8 (endobrevin)	HTATIP2	11p14.3
	35983_at	WD repeat domain 18	VAMP8	2p12-p11.2
	36083_at	sarcoma amplified sequence	WDR18	19p13.3
35	41597_s_at	SEC22 vesicle trafficking protein-like 1 (S. cerevisiae)	SAS	12q13.3
	34651_at	catechol-O-methyltransferase	SEC22L1	1q21.2-q21.3
	40774_at	chaperonin containing TCP1, subunit 3 (gamma)	COMT	22q11.21
	38410_at	centrin, EF-hand protein, 2	CCT3	1q23
			CETN2	Xq28

2052_g_at	O-6-methylguanine-DNA methyltransferase	MGMT	10q26
41171_at	proteasome (prosome, macropain) activator subunit 2 (PA28 beta)	PSME2	14q11.2
37510_at	syntaxin 8	STX8	17p12
1521_at	non-metastatic cells 1, protein (NM23A) expressed in	NME1	17q21.3
34699_at	CD2-associated protein	CD2AP	6p12
1878_g_at	excision repair cross-complementing rodent repair deficiency, complementation group 1 (includes overlapping antisense sequence)	ERCC1	19q13.2-q13.3
32051_at	hypothetical protein MGC2840 similar to a putative glucosyltransferase	MGC2840	
37033_s_at	glutathione peroxidase 1	GPX1	11pter-p15.5
38076_at	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit c ATP5G1	ATP5G1	3p21.3
37955_at	transmembrane protein 4	TMEM4	17q23.2
33908_at	calpain 1, (mu/I) large subunit	CAPN1	12q15
39728_at	interferon, gamma-inducible protein 30	IFI30	11q13
32166_at	HLA-B associated transcript 1	BAT1	19p13.1
34268_at	regulator of G-protein signalling 19	RGS19	6p21.3
36529_at	hypothetical protein MGC2650	MGC2650	20q13.3
1184_at	proteasome (prosome, macropain) activator subunit 2 (PA28 beta)	PSME2	19q13.32
38893_at	neutrophil cytosolic factor 4 (40kD)	NCF4	14q11.2
37246_at	hypothetical protein 24432	24432	22q13.1
37390_at	DEAD/H (Asp-Glu-Ala-Asp/His) box polypeptide 38	DDX38	16q22.3
41400_at	thymidine kinase 1, soluble	TK1	16q21-q22.3
36009_at	weakly similar to glutathione peroxidase 2	CL683	17q23.2-q25.3
38720_at	chaperonin containing TCP1, subunit 7 (eta)	CCT7	1q24-q41
41401_at	cysteine and glycine-rich protein 2	CSRP2	2p12
32825_at	HMT1 hnRNP methyltransferase-like 2 (S. cerevisiae)	HRMT1L2	12q21.1
410_s_at	casein kinase 2, beta polypeptide	CSNK2B	19q13.3
33447_at	myosin, light polypeptide, regulatory, non-sarcomeric (20kD)	MLCB	6p21.3
384_at	proteasome (prosome, macropain) subunit, beta type, 10	PSMB10	18p11.31
36673_at	mannose phosphate isomerase	MPI	16q22.1
37338_at	phosphoribosyl pyrophosphate synthetase-associated protein 1	PRPSAP1	15q22-qter
39795_at	adaptor-related protein complex 2, mu 1 subunit	AP2M1	17q24-q25
41749_at	chromosome 21 open reading frame 33	C21orf33	3q28
41691_at	KIAA0794 protein	KIAA0794	21q22.3
36519_at	excision repair cross-complementing rodent repair deficiency, complementation group 1 (includes overlapping antisense sequence)	ERCC1	3q29
40505_at	ubiquitin-conjugating enzyme E2L 6	UBE2L6	19q13.2-q13.3
38794_at	upstream binding transcription factor, RNA polymerase I	UBTF	11q12
			17q21.3

33441_at	T-cell leukemia translocation altered gene	TCTA	3p21
1695_at	neural precursor cell expressed, developmentally down-regulated 8	NEDD8	14q11.2
32510_at	aldo-keto reductase family 7, member A2	AKR7A2	1p35.1-p36.23
39391_at	associated molecule with the SH3 domain of STAM	AMSH	2p12
5	39073_at non-metastatic cells 1, protein (NM23A) expressed in spermidine synthase	NME1	17q21.3
241_g_at	40515_at eukaryotic translation initiation factor 2B, subunit 2 (beta, 39kD)	SRM	1p36-p22
1942_s_at	cyclin-dependent kinase 4	EIF2B2	14q24.3
36496_at	inositol(myo)-1(or 4)-monophosphatase 2	CDK4	12q14
41332_at	polymerase (RNA) II (DNA directed) polypeptide E (25kD)	IMPA2	18p11.2
32756_at	enoyl Coenzyme A hydratase 1, peroxisomal	POLR2E	19p13.3
1917_at	v-raf-1 murine leukemia viral oncogene homolog 1	ECH1	19q13.1
32544_s_at	Ras suppressor protein 1	RAF1	3p25
38242_at	B-cell linker	RSU1	10p12.31
41696_at	hypothetical protein MGC3077	BLNK	10q23.2-q23.33
37009_at	catalase	MGC3077	7p15-p14
38213_at	Bruton agammaglobulinemia tyrosine kinase	CAT	11p13
36600_at	proteasome (prosome, macropain) activator subunit 1 (PA28 alpha)	BTK	Xq21.33-q22
37543_at	Rac/Cdc42 guanine nucleotide exchange factor (GEF) 6	PSME1	14q11.2
38894_g_at	neutrophil cytosolic factor 4 (40kD)	ARHGEF6	Xq26
41146_at	ADP-ribosyltransferase (NAD+; poly (ADP-ribose) polymerase)	NCF4	22q13.1
37255_at	N-deacetylase/N-sulfotransferase (heparan glucosaminyl) 2	ADPRT	1q41-q42
37988_at	CD79B antigen (immunoglobulin-associated beta)	NDST2	10q22
37181_at	MpV17 transgene, murine homolog, glomerulosclerosis	CD79B	17q23
34773_at	tubulin-specific chaperone a	MPV17	2p23-p21
38843_at	high-mobility group protein 2-like 1	TBCA	5q13.2
38981_at	NADH dehydrogenase (ubiquinone) 1 beta subcomplex, 3	HMG2L1	22q13.1
39088_at	seven transmembrane domain protein	NDUFB3	2q31.3
35132_at	myosin IF	NIFIE14	19q13.1
30	32824_at ceroid-lipofuscinosis, neuronal 2, late infantile	MYO1F	19p13.3-p13.2
	CLN2		(Jansky-Bielschowsky disease)
35779_at	vacuolar protein sorting 45A (yeast)	11p15	
37147_at	stem cell growth factor; lymphocyte secreted C-type lectin	VPS45A	1q21-q22
39061_at	bone marrow stromal cell antigen 2	SCGF	19q13.3
36639_at	adenylosuccinate lyase	BST2	19p13.2
38435_at	peroxiredoxin 4	ADSL	22q13.2
36122_at	proteasome (prosome, macropain) subunit, alpha type, 6	PRDX4	Xp22.13
39897_at	KIAA1966 protein	PSMA6	14q13
		KIAA1966	4q13.1

2062_at	insulin-like growth factor binding protein 7	IGFBP7	4q12
CLUSTER Y			
	PROBE TITLE – CLUSTER Y	GENE SYMBOL	LOCATION
5	40281_at neural precursor cell expressed, developmentally down-regulated 5	NEDD5	2q37
	34167_s_at no title	no gene symbol	no location
	36332_at arylalkylamine N-acetyltransferase	AANAT	17q25
	38530_at hypothetical protein FLJ22709	FLJ22709	19p13.12
	36452_at synaptopodin	KIAA1029	5q33.1
10	33947_at G protein-coupled receptor 3	GPR3	1p36.1-p35
	33493_at erythroid differentiation and denucleation factor 1	HFL-EDDG1	18p11.1
	39122_at glucose phosphate isomerase	GPI	19q13.1
	36780_at clustern (complement lysis inhibitor, SP-40,40, sulfated glycoprotein 2, testosterone-repressed prostate message 2, apolipoprotein J)	CLU	8p21-p12
15	31700_at no title	no gene symbol	no location
	1448_at proteasome (prosome, macropain) subunit, alpha type, 3	PSMA3	14q23
	39965_at ras-related C3 botulinum toxin substrate 3 (rho family, small GTP binding protein Rac3)	RAC3	17q25.3
	32811_at myosin IC	MYO1C	17p13
20	31559_at solute carrier family 13 (sodium-dependent dicarboxylate transporter)	SLC13A2	17p11.1-q11.1
	33403_at DKFZP547E1010 protein	DKFZP547E1010	1q21.1
	37475_at DKFZP434J046 protein	DKFZP434J046	19q13.13
	41784_at SR rich protein	DKFZp564B0769	6q16.3
	32474_at paired box gene 7	PAX7	1p36.2-p36.12
25	33683_at no title	no gene symbol	no location
	37317_at platelet-activating factor acetylhydrolase, isoform 1b, alpha subunit	PAFAH1B1	17p13.3
	34903_at KIAA1218 protein	KIAA1218	7q22.1
	36826_at general transcription factor IIF, polypeptide 1 (74kD subunit)	GTF2F1	19p13.3
	39692_at hypothetical protein DKFZp586F2423	DKFZP586F2423	7q34
30	34753_at synaptobrevin-like 1	SYBL1	Xq28
	32329_at keratin, hair, basic, 6 (monilethrix)	KRTHB6	12q13
	32220_at high-mobility group (nonhistone chromosomal) protein 1	HMG1	13q12
	1169_at protocadherin gamma subfamily B, 7	PCDHGB7	5q31
	35670_at ATPase, Na ⁺ /K ⁺ transporting, alpha 3 polypeptide	ATP1A3	19q13.2
	31745_at mucin 3A, intestinal	MUC3A	7q22
35	38011_at RPB5-mediating protein	RMP	19q12
	943_at runt-related transcription factor 1 (acute myeloid leukemia 1; aml1 oncogene)	RUNX1	21q22.3

41799_at	DnaJ (Hsp40) homolog, subfamily C, member 7	DNAJC7	17q11.2
40539_at	myosin IXB	MYO9B	19p13.1
564_at	guanine nucleotide binding protein (G protein), alpha 11 (Gq class)	GNAI1	19p13.3
36128_at	transmembrane trafficking protein	TMP21	14q24.3
5	39486_s_at KIAA1237 protein	KIAA1237	3q21.3
36218_g_at	serine/threonine kinase 38	STK38	6p21
41202_s_at	conserved gene amplified in osteosarcoma	OS4	12q13-q15
34575_f_at	no title	no gene symbol	no location
37718_at	KIAA0096 protein	KIAA0096	3p24.3-p22.1
10	38882_r_at tripartite motif-containing 16	TRIM16	17p11.2
561_at	follicle stimulating hormone receptor	FSHR	2p21-p16
33506_at	inositol polyphosphate-4-phosphatase, type I, 107kD	INPP4A	2q11.2
40337_at	fucosyltransferase 1 (galactoside 2-alpha-L-fucosyltransferase, Bombay phenotype included)	FUT1	19q13.3
15	36024_at proline rich 4 (lacrima)	PROL4	12p13
31936_s_at	limkain b1	LKAP	16p13.2
34333_at	KIAA0063 gene product	KIAA0063	22q13.1
36845_at	KIAA0136 protein	KIAA0136	21q22.13
35530_f_at	immunoglobulin lambda joining 3	IGLJ3	22q11.1-q11.2
20	33879_at sigma receptor (SR31747 binding protein 1)	SR-BP1	9p11.2
34272_at	regulator of G-protein signalling 4	RGS4	1q23.1
40771_at	moesin	MSN	Xq11.2-q12
192_at	TAF7 RNA polymerase II, TATA box binding protein (TBP)-associated factor, 55 kD	TAF7	5q31
25	933_f_at zinc finger protein 91 (HPF7, HTF10)	ZNF91	19p13.1-p12
38181_at	matrix metalloproteinase 11 (stromelysin 3)	MMP11	22q11.23
31829_r_at	trans-golgi network protein 2	TGOLN2	2p11.2
38441_s_at	membrane cofactor protein (CD46, trophoblast-lymphocyte cross-reactive antigen)	MCP	1q32
30	39500_s_at hypothetical protein DJ46SN24.2.1	DJ46SN24.2.1	1p36.13-p35.1
34371_at	protein phosphatase 4, regulatory subunit 1	PPP4R1	18p11.21
34880_at	hypothetical protein MGC10433	MGC10433	19q13.13
35805_at	likely ortholog of rat golgi stacking protein homolog GRASP55	GRASP55	2p24.3-q21.3
41619_at	interferon regulatory factor 6	IRF6	1q32.3-q41
40468_at	formin-binding protein 17	FBP17	9q34
35292_at	HLA-B associated transcript 1	BAT1	6p21.3
38607_at	transmembrane 4 superfamily member 5	TM4SF5	17p13.3
35275_at	adaptor-related protein complex 1, gamma 1 subunit	AP1G1	16q23

36783_f_at	Krueppel-related zinc finger protein	H-plk	7p14.1
33248_at	ESTs	no gene symbol	no location
33470_at	KIAA1719 protein	KIAA1719	3p24-p23
38298_at	potassium large conductance calcium-activated channel, subfamily M beta member 1	KCNMB1	5q34
32092_at	syndecan 3 (N-syndecan)	SDC3	1pter-p22.3
39421_at	run1-related transcription factor 1 (acute myeloid leukemia 1; aml1 oncogene)	RUNX1	21q22.3
38357_at	Homo sapiens mRNA; cDNA DKFZp564D156 (from clone DKFZp564D156)	no gene symbol	no location
31819_at	Homo sapiens cDNA: FLJ23566 fis, clone LNG10880	no gene symbol	no location
41690_at	Homo sapiens mRNA; cDNA DKFZp586N012 (from clone DKFZp586N012)	no gene symbol	no location
38964_r_at	Wiskott-Aldrich syndrome (eczema-thrombocytopenia)	WAS	Xp11.4-p11.21
40839_at	ubiquitin-like 3	UBL3	13q12-q13
33543_s_at	pinin, desmosome associated protein	PNN	14q13.2
32085_at	KIAA0981 protein	KIAA0981	2q34
38752_r_at	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit e	ATP5I	4p16.3
34137_at	no title	no gene symbol	no location
41279_f_at	mitogen-activated protein kinase 8 interacting protein 1	MAPK8IP1	11p12-p11.2
442_at	tumor rejection antigen (gp96) 1	TRA1	12q24.2-q24.3
32508_at	KIAA1096 protein	KIAA1096	1q23.3
35790_at	vacuolar protein sorting 26 (yeast)	VPS26	10q21.1
40094_r_at	Lutheran blood group (Aubergier b antigen included)	LU	19q13.2
33520_at	coagulation factor VII (serum prothrombin conversion accelerator)	F7	13q34
33792_at	prostate stem cell antigen	PSCA	8q24.2
37678_at	putative transmembrane protein	NMA	10p12.3-p11.2

CLUSTER Z

PROBE	TITLE - CLUSTER Z	GENE SYMBOL	LOCATION
34400_at	low molecular mass ubiquinone-binding protein (9.5kD)	QP-C	5q31.1
39921_at	cytochrome c oxidase subunit Vb	COX5B	2cen-q13
40546_s_at	NADH dehydrogenase (ubiquinone) 1 alpha subcomplex, 2 (8kD, B8)	NDUFA2	5q31
38085_at	chromobox homolog 3 (HP1 gamma homolog, Drosophila)	CBX3	7p21.1
39778_at	mannosyl (alpha-1,3-)-glycoprotein beta-1,2-N-acetylglucosaminyltransferase	MGAT1	5q35
36600_at	proteasome (prosome, macropain) activator subunit 1 (PA28 alpha)	PSME1	14q11.2
40433_at	Homo sapiens, clone IMAGE:4391536, mRNA	no gene symbol	no location

35767	at	GABA(A) receptor-associated protein-like 2	GABARAPL2	16q22.3-q24.1
1450	g	at proteasome (prosome, macropain) subunit, alpha type, 4	PSMA4	15q24.2
33738	r	at Homo sapiens cervical cancer suppressor-1 mRNA, complete cds	no gene symbol	no location
40134	at	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit f, isoform 2	ATP5J2	7q11.21
567	s	at promyelocytic leukemia	PML	15q22
40881	at	ATP citrate lyase	ACLY	17q12-q21
38974	at	RNA-binding protein regulatory subunit	DJ-1	1p36.33-p36.12
33819	at	lactate dehydrogenase B	LDHB	12p12.2-p12.1
40854	at	ubiquinol-cytochrome c reductase core protein II	UQCRC2	16p12
41694	at	BN51 (BHK21) temperature sensitivity complementing	BN51T	8q21
38771	at	histone deacetylase 1	HDAC1	1p34
40792	s	at triple functional domain (PTPRF interacting)	TRIO	5p15.1-p14
970	r	at ubiquitin specific protease 9, X chromosome (fat facets-like Drosophila)	USP9X	Xp11.4
34381	at	cytochrome c oxidase subunit VIIc	COX7C	5q14
35992	at	musculin (activated B-cell factor-1)	MSC	8q21
40774	at	chaperonin containing TCP1, subunit 3 (gamma)	CCT3	1q23
32701	at	arnadillo repeat gene deletes in velocardiofacial syndrome	ARVCF	22q11.21
33011	at	neurotensin receptor 2	NTSR2	no location
36676	at	ribophorin II	RPN2	20q12-q13.1
33510	s	at glutamate receptor, metabotropic 1	GRM1	6q24
37866	at	Homo sapiens mRNA full length insert cDNA clone EUROIMAGE 29222	no gene symbol	no location
41175	at	core-binding factor, beta subunit	CBFB	16q22.1
39920	r	at C1q-related factor	CRF	17q21
32550	r	at CCAAT/enhancer binding protein (C/EBP), alpha	CEBPA	19q13.1
32104	i	at calcium/calmodulin-dependent protein kinase (CaM kinase) II gamma	CAMK2G	10q22
39747	at	polymerase (RNA) II (DNA directed) polypeptide G	POLR2G	11q13.1
38516	at	sodium channel, voltage-gated, type I, beta polypeptide	SCN1B	19q13.1
39131	at	similar to yeast Upf3, variant A	UPF3A	13q34
35297	at	NADH dehydrogenase (ubiquinone) 1, alpha/beta subcomplex, 1	NDUFAB1	16p11.2
40764	at	glutamic-oxaloacetic transaminase 2, mitochondrial (2)	GOT2	16q21
41833	at	jumping translocation breakpoint	JTB	1q21
39741	at	hydroxyacyl-Coenzyme A dehydrogenase/3-ketoacyl-Coenzyme A thiolase/enoyl-Coenzyme A hydratase (trifunctional protein)	HADHB	2p23
34894	r	at protease, serine, 22	PRSS22	16p13.3
37796	at	leucine-rich repeat protein, neuronal 1	LRRN1	7q22

36355_at	involucrin	IVL	1q21
1072_g_at	GATA binding protein 2	GATA2	3q21
33447_at	myosin, light polypeptide, regulatory, non-sarcomeric (20kD)	MLCB	18p11.31
39448_r_at	B7 protein	B7	12p13
5	37337_at small nuclear ribonucleoprotein polypeptide G	SNRPG	2p12
37414_at	solute carrier family 22 (organic cation transporter), member 1-like	SLC22A1LS	11p15.5
41255_at	Homo sapiens mRNA; cDNA DKFZp434E0528	no gene symbol	no location
721_g_at	heat shock transcription factor 4	HSF4	16q21
39184_at	transcription elongation factor B (SIII), polypeptide 2 (elongin B)	TCEB2	13
40189_at	SET translocation (myeloid leukemia-associated)	SET	9q34
37677_at	phosphoglycerate kinase 1	PGK1	Xq13
34602_at	ficolin (collagen/fibrinogen domain containing lectin) 2 (hucolin)	FCN2	9q34
41374_at	ribosomal protein S6 kinase, 70kD, polypeptide 2	RPS6KB2	11q12.2
40467_at	succinate dehydrogenase complex, subunit D, integral protein	SDHD	11q23
33137_at	latent transforming growth factor beta binding protein 4	LTBP4	19q13.1-q13.2
36826_at	general transcription factor IIF, polypeptide 1 (74kD subunit)	GTF2F1	19p13.3
37546_r_at	secretory carrier membrane protein 5	SCAMP5	no location
33632_g_at	similar to S. pombe dim1+	DIM1	18q23
41146_at	ADP-ribosyltransferase (NAD+; poly (ADP-ribose) polymerase)	ADPRT	1q41-q42
36188_at	general transcription factor IIIA	GTF3A	13q12.3-q13.1
20	32511_at ESTs	no gene symbol	no location
39795_at	adaptor-related protein complex 2, mu 1 subunit	AP2M1	3q28
396_f_at	erythropoietin receptor	EPOR	19p13.3-p13.2
31497_at	G antigen 1	GAGE1	Xp11.4-p11.2
25	34573_at ephrin-A3	EFNA3	1q21-q22
37668_at	complement component 1, q subcomponent binding protein	CIQB	17p13.3
37348_s_at	thyroid hormone receptor interactor 7	TRIP7	6q15
37766_s_at	prosome, macropain) 26S subunit, ATPase, 5	PSMC5	17q23-q25
34380_at	stomatin (EPB72)-like 2	STOML2	9p13.1
30	39174_at nuclear receptor coactivator 4	NCOA4	10q11.2
36032_at	HSPCO34 protein	LOC51668	1p32.1-p33
160020_at	matrix metalloproteinase 14 (membrane-inserted)	MMP14	14q11-q12
34783_s_at	BUB3 budding uninhibited by benzimidazoles 3 homolog (yeast)	BUB3	10q26
33027_at	no title	no gene symbol	no location
35	38368_at dUTP pyrophosphatase	DUT	15q15-q21.1
36688_at	sterol carrier protein 2	SCP2	1p32
38251_at	myosin light chain 1 slow a	MLC1SA	12q13.13
39803_s_at	chromosome 21 open reading frame 2	C21orf2	21q22.3

35734_at ARP2 actin-related protein 2 homolog (yeast)
32004_s_at cell division cycle 2-like 2
1827_s_at v-myc myelocytomatosis viral oncogene homolog (avian)
32530_at tyrosine 3-monooxygenase/tryptophan 5-monooxygenase activation
protein, theta polypeptide
33727_r_at tumor necrosis factor receptor superfamily, member 6b, decoy
34970_r_at 5-oxoprolinase (ATP-hydrolysing)
36122_at proteasome (prosome, macropain) subunit, alpha type, 6
32849_at SMC1 structural maintenance of chromosomes 1-like 1 (yeast)
31812_at guanosine monophosphate reductase
36218_g_at serine/threonine kinase 38

ACTR2
CDC2L2
MYC
YWHAQ
TNFRSF6B
OPLAH
PSMA6
SMC1L1
GMPR
STK38

2p14
1p36.3
8q24.12-q24.13
22q12-qter
20q13.3
8
14q13
Xp11.22-p11.21
6p23
6p21

CLUSTERS S1 + S2 VERSUS ALL OTHER CLUSTERS

PROBE TITLE - S1 + S2 against the rest
38319_at CD3D antigen, delta polypeptide (TIT3 complex)
38147_at SH2 domain protein 1A, Duncan's disease (lymphoproliferative
syndrome)
39226_at CD3G antigen, gamma polypeptide (TIT3 complex)
33238_at lymphocyte-specific protein tyrosine kinase
2059_s_at lymphocyte-specific protein tyrosine kinase
32794_g_at T cell receptor beta locus
31891_at chitinase 3-like 2
38949_at protein kinase C, theta
37344_at major histocompatibility complex, class II, DM alpha
38095_i_at major histocompatibility complex, class II, DP beta 1
38096_f_at major histocompatibility complex, class II, DP beta 1
38051_at mal, T-cell differentiation protein
40688_at linker for activation of T cells
1096_g_at CD19 antigen
1105_s_at T cell receptor beta locus
40954_at FXYD domain-containing ion transport regulator 2
35016_at CD74 antigen (invariant polypeptide of major histocompatibility
complex, class II antigen-associated)
40775_at integral membrane protein 2A
40738_at CD2 antigen (p50), sheep red blood cell receptor
38547_at integrin, alpha L (antigen CD11A (p180), lymphocyte function-
associated antigen 1; alpha polypeptide)
36277_at CD3E antigen, epsilon polypeptide (TIT3 complex)

GENE SYMBOL
CD3D
SH2D1A
CD3G
LCK
LCK
TRB@
CHI3L2
PRKCQ
HLA-DMA
HLA-DPB1
HLA-DPB1
MAL
LAT
CD19
TRB@
FXYD2
CD74
ITM2A
CD2
ITGAL
CD3E

LOCATION
11q23
Xq25-q26
11q23
1p34.3
1p34.3
7q34
1p13.3
10p15
6p21.3
6p21.3
6p21.3
2cen-q13
no location
16p11.2
7q34
11q23
5q32
Xq13.3-Xq21.2
1p13
16p11.2
11q23

5	41165_g_at immunoglobulin heavy constant mu	IGHM	14q32.33
	41523_at RAB32, member RAS oncogene family	RAB32	6q24.3
	38315_at aldehyde dehydrogenase 1 family, member A2	ALDH1A2	15q21.1-q21.2
	38917_at T cell receptor delta locus	TRD@	14q11.2
	38833_at major histocompatibility complex, class II, DP alpha 1	HLA-DPA1	6p21.3
10	39119_s_at natural killer cell transcript 4	NK4	16p13.3
	40147_at vesicle amine transport protein 1	VATI	17q21
	37039_at major histocompatibility complex, class II, DR alpha	HLA-DRA	6p21.3
	1110_at T cell receptor delta locus	TRD@	14q11.2
	39709_at selenoprotein W, 1	SEPW1	19q13.3
15	771_s_at CD7 antigen (p41)	CD7	17q25.2-q25.3
	41164_at immunoglobulin heavy constant mu	IGHM	14q32.33
	39248_at aquaporin 3	AQP3	9p13
	34927_at CD1B antigen, b polypeptide	CD1B	1q22-q23
	37399_at aldo-keto reductase family 1, member C3 (3-alpha hydroxysteroid dehydrogenase, type II)	AKRIC3	10p15-p14
20	1498_at zeta-chain (TCR) associated protein kinase (70 kD)	ZAP70	2q12
	39930_at EphB6	EPHB6	7q33-q35
	40570_at forkhead box O1A (rhabdomyosarcoma)	FOXO1A	13q14.1
	37861_at CD1E antigen, e polypeptide	CD1E	1q22-q23
	37078_at CD3Z antigen, zeta polypeptide (TtT3 complex)	CD3Z	1q22-q23
25	35643_at nucleobindin 2	NUCB2	11p15.1-p14
	38017_at CD79A antigen (immunoglobulin-associated alpha)	CD79A	19q13.2
	38408_at transmembrane 4 superfamily member 2	TM4SF2	Xq11.4
	41166_at immunoglobulin heavy constant mu	IGHM	14q32.33
	605_at vesicle amine transport protein 1	VATI	17q21
30	245_at selectin L (lymphocyte adhesion molecule 1)	SELL	1q23-q25
	2047_s_at junction plakoglobin	JUP	17q21
	2031_s_at cyclin-dependent kinase inhibitor 1A (p21, Cip1)	CDKN1A	6p21.2
	33236_at retinoic acid receptor responder (tazarotene induced) 3	RARRES3	11q23
	32649_at transcription factor 7 (T-cell specific, HMG-box)	TCF7	5q31.1
35	36773_f_at major histocompatibility complex, class II, DQ beta 1	HLA-DQB1	6p21.3
	38750_at Notch homolog 3 (Drosophila)	NOTCH3	19p13.2-p13.1
	41609_at major histocompatibility complex, class II, DM beta	HLA-DMB	6p21.3
	32793_at T cell receptor beta locus	TRB@	7q34
	38893_at neutrophil cytosolic factor 4 (40kD)	NCF4	22q13.1
	41723_s_at major histocompatibility complex, class II, DR beta 1	HLA-DRB1	6p21.3
	37403_at annexin A1	ANXA1	9q12-q21.2

36473_at	ubiquitin specific protease 20	USP20	9q34.12-q34.13
36941_at	ALL1-fused gene from chromosome 1q	AF1Q	1q21
39319_at	lymphocyte cytosolic protein 2 (SH2 domain-containing leukocyte protein of 76kD)	LCP2	5q33.1-qter
5	36878_f at major histocompatibility complex, class II, DQ beta 1	HLA-DQB1	6p21.3
907_at	adenosine deaminase	ADA	20q12-q13.11
33121_g	at regulator of G-protein signalling 10	RGS10	10q25
41468_at	T cell receptor gamma locus	TRG@	7p15-pl4
37849_at	slit homolog 1 (Drosophila)	SLIT1	10q23.3-q24
10	38253_at amylo-1, 6-glucosidase, 4-alpha-glucanotransferase (glycogen debranching enzyme, glycogen storage disease type III)	AGL	1p21
34033_s	at leukocyte immunoglobulin-like receptor, subfamily A (with TM domain), member 2	LILRA2	19q13.4
41819_at	FYN binding protein (FYB-120/130)	FYB	5p13.1
15	35985_at A kinase (PRKA) anchor protein 2	AKAP2	9q31-q33
33821_at	at homolog of yeast long chain polyunsaturated fatty acid elongation enzyme 2	HELO1	6p21.1-p12.1
172_at	inositol polyphosphate-5-phosphatase, 145kD	INPP5D	2q36-q37
37759_at	Lysosomal-associated multispinning membrane protein-5	LAPTM5	1p34
20	36937_s at PDZ and LIM domain 1 (elfin)	PDLIM1	10q22-q26.3
33641_g	at allograft inflammatory factor 1	AIF1	6p21.3
41156_g	at catenin (cadherin-associated protein), alpha 1 (102kD)	CTNNA1	5q31
37890_at	CD47 antigen (Rh-related antigen, integrin-associated signal transducer)	CD47	3q13.1-q13.2
25	39273 at ESTs	no gene symbol	no location
41409_at	basement membrane-induced gene	ICB-1	1p35.3
40155_at	actin binding LIM protein	ABLIM	10q25
33291_at	RAS guanyl releasing protein 1 (calcium and DAG-regulated)	RASGRP1	15q15
36658_at	24-dehydrocholesterol reductase	DHCR24	1p33-p31.1
38581_at	guanine nucleotide binding protein (G protein), q polypeptide	GNAQ	9q21
33316_at	KIAA0808 gene product	TOX	8q12.2-q12.3
37598_at	Ras association (RalGDS/AF-6) domain family 2	RASSF2	20pter-p12.1
36808_at	protein tyrosine phosphatase, non-receptor type 22 (lymphoid)	PTPN22	1p13.3-p13.1
39044_s	at diacylglycerol kinase, delta (130kD)	DGKD	2q37.1
35	39318_at T-cell leukemia/lymphoma 1A	TCL1A	14q32.1
33777_at	thromboxane A synthase 1 (platelet, cytochrome P450, subfamily V)	TBXASI	7q34-q35

CLUSTER S1 vs. S2

PROBE	TITLE – S1 vs. S2	GENE SYMBOL	LOCATION
32528_at	ClpP caseinolytic protease, A TP-dependent, homolog (E. coli)	CLPP	19p13.3
34182_at	N-deacetylase/N-sulfotransferase (heparan glucosaminyl) 1	NDST1	5q32-q33.1
36158_at	dynactin 1 (p150, glued homolog, Drosophila)	DCTN1	2p13
36276_at	contactin 2 (axonal)	CNTN2	1q32.1
39917_at	gamma-tubulin complex protein 2	GCP2	10q26.3
1942_s_at	cyclin-dependent kinase 4	CDK4	12q14
31559_at	solute carrier family 13 (sodium-dependent dicarboxylate transporter)	SLC13A2	17p11.1-q11.1
121_at	paired box gene 8	PAX8	2q12-q14
36126_at	nucleotide binding protein	NBP	17q12-q21
31391_at	huntingtin-associated protein 1 (neuroan 1)	HAPI	17q21.2-q21.3
33448_at	serine protease inhibitor, Kunitz type 1	SPINT1	15q13.3
37905_r_at	no title	no gene symbol	no location
35727_at	uridine kinase-like 1	URKL1	20q13.33
38998_g_at	solute carrier family 25 (mitochondrial carrier; citrate transporter)	SLC25A1	22q11.21
40862_i_at	creatine kinase, brain	CKB	14q32
2025_s_at	APEX nuclease (multifunctional DNA repair enzyme)	APEX	14q11.2-q12
33493_at	erythroid differentiation and denucleation factor 1	HFL-EDDG1	18p11.1
396_f_at	erythropoietin receptor	EPOR	19p13.3-p13.2
40115_at	CCR4-NOT transcription complex, subunit 7	CNOT7	8p22-p21.3
33640_at	allograft inflammatory factor 1	AIF1	6p21.3
40094_r_at	Lutheran blood group (Aubergier b antigen included)	LU	19q13.2
1309_at	proteasome (prosome, macropain) subunit, beta type, 3	PSMB3	2q35
39920_r_at	C1q-related factor	CRF	17q21
40299_at	G-protein coupled receptor	RE2	1q23.2
1280_i_at	no title	no gene symbol	no location
33011_at	neurotensin receptor 2	NTSR2	no location
34963_at	no title	no gene symbol	no location
38442_at	microfibrillar-associated protein 2	MFAP2	1p36.1-p35
1827_s_at	v-myc myelocytomatosis viral oncogene homolog (avian)	MYC	8q24.12-q24.13
33706_at	squamous cell carcinoma antigen recognised by T cells	SART1	11q12.1
41184_s_at	proteasome (prosome, macropain) subunit, beta type, 8 (large multifunctional protease 7)		
40817_at	nucleobindin 1	PSMB8	6p21.3
32335_r_at	ubiquitin C	NUCB1	19q13.2-q13.4
38964_r_at	Wiskott-Aldrich syndrome (eczema-thrombocytopenia)	UBC	12q24.3
34970_r_at	5-oxoprolinase (ATP-hydrolysing)	WAS	Xp11.4-p11.21
34539_at	olfactory receptor, family 7, subfamily A, member 126 pseudogene	OPLAH	8
		OR7E126P	11

36565_at	zinc finger protein 183 (RING finger, C3HC4 type)	ZNF183	Xq25-q26
160044_g_at	aconitase 2, mitochondrial	ACO2	22q13.2-q13.31
41034_s_at	sulfotransferase family, cytosolic, 2B, member 1	SULT2B1	19q13.3
39731_at	RNA binding motif protein, X chromosome	RBMX	Xq26
567_s_at	promyelocytic leukemia	PML	15q22
870_f_at	metallothionein 3 (growth inhibitory factor (neurotrophic))	MT3	16q13
327_f_at	no title	no gene symbol	no location
33132_at	cleavage and polyadenylation specific factor 1, 160kD subunit	CPSF1	8q24.23
36600_at	proteasome (prosome, macropain) activator subunit 1 (PA28 alpha)	PSME1	14q11.2
39965_at	ras-related C3 botulinum toxin substrate 3 (rho family, small GTP binding protein Rac3)	RAC3	17q25.3
1053_at	replication factor C (activator 1) 2 (40kD)	RFC2	7q11.23
32007_at	no title	no gene symbol	no location
36452_at	synaptopodin	KIAA1029	5q33.1
884_at	integrin, alpha 3 (antigen CD49C, alpha 3 subunit of VLA-3 receptor)	ITGA3	17q23.3
36881_at	electron-transfer-flavoprotein, beta polypeptide	ETFB	19q13.3
34166_at	solute carrier family 6 (neurotransmitter transporter, L-proline), member 7	SLC6A7	5q31-q32
33247_at	26S proteasome-associated pad1 homolog	POH1	2q24.3
32104_i_at	calcium/calmodulin-dependent protein kinase (CaM kinase) II gamma	CAMK2G	10q22
35385_at	COQ7 coenzyme Q, 7 homolog ubiquinone (yeast)	COQ7	16p13.11-p12.3
31745_at	mucin 3A, intestinal	MUC3A	7q22
35595_at	ESTs, Highly similar to calcitonin gene-related peptide-receptor component protein [Homo sapiens] [H.sapiens]	no gene symbol	no location
41703_r_at	A kinase (PRKA) anchor protein 7	AKAP7	6q23
39608_at	single-minded homolog 2 (Drosophila)	SIM2	21q22.13
37885_at	hypothetical protein AF038169	AF038169	2q22.1
1470_at	polymerase (DNA directed), delta 2, regulatory subunit (50kD)	POLD2	7p15.1
37766_s_at	proteasome (DNA directed), delta 2, regulatory subunit (50kD)	PSMC5	17q23-q25
34302_at	proteasome (prosome, macropain) 26S subunit, ATPase, 5	EIF3S4	19p13.2
40441_g_at	eukaryotic translation initiation factor 3, subunit 4 (delta, 44kD)	PAI-RBP1	1p31-p22
36218_g_at	PAI-1 mRNA-binding protein	STK38	6p21
36218_g_at	serine/threonine kinase 38	NASP	8q11.23
33255_at	nuclear autoantigenic sperm protein (histone-binding)	LSM3	3p25.1
39009_at	Lsm3 protein	PPP3CC	8p21.2
32540_at	protein phosphatase 3 (formerly 2B), catalytic subunit, gamma isoform (calcineurin A gamma)		

35911_r_at	matrix metalloproteinase-like 1	MMPL1	16p13.3
39937_at	chemokine (C-C motif) receptor 2	CCR2	3p21
1553_r_at	no title	no gene symbol	no location
31550_at	adrenergic, beta-1-, receptor	ADRB1	10q24-q26
1446_at	proteasome (prosome, macropain) subunit, alpha type, 2	PSMA2	7p15.1
36004_at	inhibitor of kappa light polypeptide gene enhancer in B-cells, kinase gamma	IKBK	Xq28
1494_f_at	cytochrome P450, subfamily IIA (phenobarbital-inducible), polypeptide 6	CYP2A6	19q13.2
41458_at	KIAA0467 protein	KIAA0467	1p34.1
36125_s_at	RNA binding protein (autoantigenic, hnRNP-associated with lethal yellow)	RALY	20q11.21-q11.23
33349_at	Homo sapiens mRNA; cDNA DKFZp58611518	no gene symbol	no location
38682_at	BRCA1 associated protein-1 (ubiquitin carboxy-terminal hydrolase)	BAP1	3p21.31-p21.2
34577_at	melanoma antigen, family A, 9	MAGEA9	Xq28
35096_at	solute carrier family 1 (high affinity aspartate/glutamate transporter)	SLC1A6	19p13.13
34573_at	ephraim-A3	EFNA3	1q21-q22
33071_at	H2B histone family, member N	H2BFN	6p22-p21.3
34894_r_at	protease, serine, 22	PRSS22	16p13.3
39448_r_at	B7 protein	B7	12p13
32190_at	fatty acid desaturase 2	FADS2	11q12-q13.1
34325_at	polyglutamine binding protein 1	PQBP1	Xp11.23
33168_at	Homo sapiens cDNA: FLJ23067 fis, clone LNG04993	no gene symbol	no location
32681_at	solute carrier family 9 (sodium/hydrogen exchanger), isoform 1 (antiporter, Na+/H+, amiloride sensitive)	SLC9A1	1p36.1-p35

EXAMPLE XIII

Gene Expression Profiling for Molecular Classification and Outcome Prediction in Infant Leukemia Reveals Novel Biologic Clusters, Etiologies and Pathways for Treatment Failure

5

To determine if traditional biologic and clinical subgroups of infant leukemia cases could be identified by gene expression profiles, 126 infant leukemia cases registered to NCI-sponsored Infant Oncology Group/Children's Oncology Group treatment trials were studied using oligonucleotide microarrays containing 12,625 probe sets (Affymetrix U95Av2 array platform). Of the 126 cases, 78 were ALL (62%), 48 were AML (38%) and 53 (42%) cases had translocations involving the *MLL* gene (chromosome segment 11q23).

The exploratory evaluation of our data set was performed in several steps. The first step of the analysis was the construction of predictive classification algorithms that linked the gene expression data to the traditional clinical variables that define treatment, using supervised learning techniques, and further, the exploration of patterns that could predict patient outcomes. As described in Example IA, the 126 patients were divided into statistically balanced and representative training (82 patients) and test sets (44 patients), according to the clinical labels (leukemia lineage, cytogenetics and outcome). For classification purposes, two primary supervised approaches were used; Bayesian networks and recursive feature elimination in the context of Support Vector Machines (SVM-RFE). Additional classification techniques (Fuzzy inference and Discriminant Analysis) were used for comparison purposes.

All of the classification algorithms were established based on the training data set and then used to predict the class of the samples in the test. Two statistical significance tests were employed to further evaluate the prediction accuracy of those algorithms. The first tested whether the success rate of each classification algorithm was significantly greater than the value that would be expected by chance alone (i.e. whether the success rate was significantly greater than 0.5, where the success rate = # of correct predictions / total predictions). The second prediction accuracy test used the true positive proportion (TP) and false positive proportion (FP) value computed for one of the two classes. For a binary classification problem, TP is the ratio of correctly classified samples in the class to the total number in the class. FP is the proportion of

misclassified samples in the other class to the total number in that class. To test whether the true positive proportion was significantly greater than the false positive proportion, we used Fisher's exact test. The p-values of the two tests along with the success rates for each of the classification algorithms with respect to the classification tasks of interest are listed in Table 44. As shown in the table, both evaluation methods confirmed that the classification results for the lineage labels (ALL/AML) and the presence or absence of t(4;11) rearrangements were significant at level $\alpha=0.05$. In other words, all the supervised learning techniques employed were successful in finding a distinction between ALL and AML samples, and the presence/absence of t(4;11) rearrangements. Detailed gene lists that characterize each one of these leukemia subtypes were obtained from all the classifiers used and can be found in the Supplemental Information.

Class discovery: Expression profiles partition infant leukemia cases in three groups

To explore the intrinsic structure of the data independent of known class labels, several unsupervised clustering methods were employed. These unsupervised approaches allowed patient separation into potential clusters based on overall similarity in gene expression, without prior knowledge of clinical labels. As discussed below, although certain degree of correlation of our unsupervised clusters with traditional lineage (ALL/AML) and cytogenetics (MLL or not) could be observed, those labels were not enough to completely explain the results of our unsupervised clustering methods, suggesting that leukemia lineage and cytogenetics are not the only important factors in driving the inherent biology of these gene expression groups.

Initially, the data were investigated using agglomerative hierarchical clustering (Eisen *et al.*, 1998). Hierarchical clustering results from the 126 infant leukemia samples using all genes yielded several groups that seemed to have no relation to the known lineage labels or the partition of the data suggested by the presence or absence of *MLL* rearrangements (see supplemental information).

The next technique used was Principal Component Analysis (PCA). PCA, closely related to the Singular Value Decomposition (SVD), is an unsupervised data analysis method whereby the most variance is captured in the least number of coordinates (Jolliffe, 1986; Kirby, 2001; Trefethan & Bau, 1997). As shown in Fig. 9, the first three principal components can be seen to partition the infant cohort into two different groups. These groups capture the infant ALL/AML lineage distinction, but

only weakly agree with the MLL cytogenetics. Specifically, there is a 92% agreement between the PCA and the ALL/AML labels and only a 65% agreement between the PCA and MLL/non-MLL labels. Unexpectedly, the ALL/AML distinction does not appear until the second principal component, suggesting that morphology is not the most important factor explaining the variance in our data set. However, the first (and most important) principal component does not reveal any obvious clusters. Upon further analysis with a force-directed graph layout algorithm, we found the additional group (discussed later) seen only in the first principal component (colored in blue in Fig. 9).

The force-directed clustering algorithm (Davidson *et al.*, 1998; 2001) places patients into clusters on the two-dimensional plane by minimizing two opposing forces. Briefly, the algorithm forms groups of patients by iteratively moving them toward one another with small steps proportional to the similarity of their gene expression, as measured by Pearson's correlation coefficient. To avoid collecting all of the patients into a single group, a counteracting force pushes nearby patients away from each other. This force increases in proportion to the number of nearby patients and has a strong local effect, thus acting to disperse any concentrated group of patients. This force affects only patients who are near each other, while the attractive force (Pearson's similarity) is independent of distance. The algorithm moves patients into a configuration that balances these two forces, thus grouping patients with similar gene expression. The spatial distribution of patients is then visualized on a three-dimensional plot, similar to a terrain map, where the height of the peaks denotes the local density of patients. This method has been useful in inferring functions of uncharacterized genes clustered near other genes with known functions (Kim, 2001) and for the analysis and mapping of various databases (Davidson, 1998, Werner-Washburne, 2002)

When applied to the infant data, the VxInsight clustering algorithm identifies several pattern of gene expression across the patients, suggesting the existence of three major groups (Fig. 10, and row three in Fig. 9), which hereafter will be denoted clusters A, B, and C. Despite different means of data transformation and different underlying mathematics, a high degree of overlap (92%) was observed between the clusters derived from PCA and the B and C clusters identified through the clustering algorithm native to *VxInsight*®. In addition, when the A group is displayed in the PCA projections (as seen in row three of Fig. 9), we see that it is distinguished from

the B and C clusters in the first principal component. This lends additional support to the existence of and the importance of the A group.

Several further explorations into the *VxInsight* clusters were pursued. Linear discriminant analysis was used to separate the three clusters. The object of
5 discriminant analysis is to weight and linearly combine information from the feature variables in a manner that clearly distinguishes labeled subclasses of the data. More specifically, the idea is to find a linear function of the feature variables such that the value of this function differs significantly between different classes. This function is the so-called discriminant function. Then, ANOVA was performed to rank cluster-
10 discriminating genes in term of their F-test statistic values. From the top genes, a subset of genes was selected using stepwise discriminant analysis. This subset of genes served as the discriminating variables needed by linear discriminant analysis. The error rate of the derived classification results was 0.03, as estimated using fold-independent leave one out cross-validation (LOOCV). This indicated that the three
15 *VxInsight* clusters were well separated.

There was also support for the existence of the *VxInsight* groupings even when only a subset of the data was used. For example, three widely separated groups of patients were observed when using only the patients in the training set. The addition of the rest of the patients in the test set, however, did induce change. In
20 particular, the cores of Groups A and Groups C remained separated while Group B increased to include marginal members of groups A and C. The observation of similar grouping in both the entire set and the training set alone increased our interest in discerning the force driving the clustering for the patients in the *VxInsight* groups.

Finally, we confirmed our ability to classify patients into the *VxInsight* groups
25 A, B, and C. Such a demonstration showed that we could categorize new patients into our grouping in the future (e.g. for treatment or diagnosis). To accomplish this, a multi-class Support Vector Machine (SVM) was trained using the actual labels A, B, and C in the patients from the training set. The prediction accuracy of this SVM on the test set was 95%. To verify that this result was improbable by chance alone, a
30 randomization test was also performed. The labels A, B and C were randomly reassigned to the patients in both the training and the test set. Then, another SVM was trained with the re-labeled data in the training set. This SVM achieved a prediction accuracy of only 40% on the test set.

Subsequent exploration of the cluster-characterizing genes was performed using analysis of variance (ANOVA). The F-scores from this method were used to order all of the genes with respect to differential expressions between the groups. The strongest ranking 100 genes were then tabulated. The stability and strength of these gene lists was studied using statistical bootstrapping (Efron, 1979; Hjorth, 1994). This analysis provided a powerful method for determining the likelihood that a gene (high on the gene list determined from the actual data) would remain near the top of any gene list generated from experimental data similar to that which we actually observed. While this method allowed the identification of genes that had a unique pattern in each cluster and defined inter-clusters differences, it is important to make a distinction between these genes and the ones active in each one of the clusters (See supplemental information). Some very surprising findings were uncovered after completing a detailed analysis of the genes responsible for the distinction between clusters. These results, together with the stability of the clusters, suggest that the identified groups represent well-separated patient subclasses.

Approaches to inherent biology

Expression profiles identified different clusters of infant leukemia cases, not related to type labels or cytogenetics, but characterized by different genes predominantly expressed in, and probably related to, three independent disease initiation mechanisms. The sets of cluster-discriminating genes can be used to identify each biologic group and hence represent potentially important diagnostic and therapeutic targets (See Table 45). A heat map/dendrogram was produced with the top 30 genes that characterized each one of the three clusters, generated from the ANOVA analysis. Analysis of these genes revealed patterns that imply different features with potential clinical relevance.

The top cluster of cases (Fig. 10, cluster A, n=20, 15 ALL cases and 5 AML cases) has a gene expression profile that would not be recognized as "leukemic" *per se*. The cases in this cluster are distinguished by high expression of genes such as the novel tumor suppressor gene (ST5), embryonal antigens, adhesion molecules (particularly integrin $\alpha 3$), growth factor receptors for numerous lineages (keratinocytes and epithelial cells, hepatocytes, neuronal cells, and hematopoietic cells) and genes in the TGFB1 signaling pathway. The TGFB cytokines modulate the

growth and functions of a wide variety of mammalian cell types. TGFB inhibits the proliferation of most types of cells. Proteins such as the latent transforming growth factor beta binding protein 4 (LTBP4), which is over expressed in this group of patients, are also regulated by TGFB. (Oklu, 2000). For this particular group of patients, cluster-discriminant genes such as CD34 (hematopoietic progenitor cell antigen), ataxin 2 related protein (responsible for specific stages of both cerebellar and vertebral column development), contactin2 (involved in glial development and tumorigenesis), the ski oncogene (another component of the TGFB1 signaling pathway) and the erythropoietin receptor, suggest the involvement of an embryonal "common progenitor" primordial cell. Additionally, despite high expression of the above-mentioned characteristic genes, cases in this cluster demonstrated low to moderate expression of most genes. These data supports recent reports of stepwise decrease in transcriptional accessibility for multilineage-affiliated genes may represent progressive restriction of development potentials in early hematopoiesis ((Akashi et al., Blood 2003 Jan 15;101(2):383-9)). As suggested by Akashi et al, the size of the "functional genome" may be progressively reduced as hematopoietic stem cells undergo differentiation.

Other genes in this group with an absolutely unique pattern of expression include growth inhibitory factors like methallothionein 3 (*MT3*), embryonic cell transcription factors (*UTF1*) and stem cell antigens (prostate stem cell antigen) with remarkable homology to cell surface proteins that characterize the earliest phases of hematopoietic development (Reiter, 1998).

The left cluster of cases (Fig. 10, cluster B, n=52, 51 ALL cases and 1 AML case), is characterized by a high frequency of *MLL* rearrangements, predominantly t(4; 11). This group was also distinguished by expression of lymphoid-characterizing genes (CD19, B lymphoid tyrosine kinase, CD79a) as well as EBV infection-related genes and genes associated with, or induced by, other DNA viruses. It is especially remarkable to find elevated expression of the Epstein-Barr virus-induced gene 2 (EBI2) in more than 30% of the cases in this cluster (*82% of this cases have *MLL* rearrangements). EBI2 has been reported as one of the genes present in EBV infected B-lymphocytes (Birkenbach, 1993). Epstein-Barr virus infection of B lymphocytes, as well as infection of Burkitt lymphoma cells, induces an increase in the expression of this gene, identifiable by subtractive hybridization. We speculate that this group of

cases might be initiated by a viral infection and that secondary, but critical MLL translocations stabilize or, alternatively, more fully transform these cells.

Finally, the third rightmost cluster (Fig. 9, cluster C, n=54, 42 AML cases and 12 ALL cases) is more heterogeneous and has a broader spectrum of *MLL* translocations. The gene expression signature of this group seems to have "myeloid" characteristics, with activation of genes previously reported as "myeloid-specific" such as Cystatin C (CST3), the myeloid cell nuclear differentiation factor (MND4), and CCAAT/enhancer binding protein delta (C/EBP) (Golub, 1999; Skalnik, 2002). Members of the CCAAT/enhancer binding protein (C/EBP) family of transcription factors are important regulators of myeloid cell development (Skalnik, 2002). Other genes useful for cluster C prediction may also provide new insights into infant leukemia pathogenesis. For example, the mitogen activated protein kinase-activated protein kinase 3 is the first kinase to be activated through all 3 MAPK cascades: extracellular signal-regulated kinase (ERK), MAPKAP kinase-2, and Jun-N-terminal kinases/stress-activated protein kinases (Ludwig, 1996). It has been demonstrated as a determinant integrative element of signaling in both mitogen and stress responses. MAPKAPK3 showed high relative expression in the patients in cluster C. Many of the genes that characterize this cluster encode proteins characteristic of definitive myeloid differentiation (NDUFAB1, SOD1, GSTTLP28), or which are critical for signal transduction (TYROBP). Interestingly, activation of many DNA repair and GST genes was also evident in this group of cases.

Altogether, the results of our class discovery methods suggested that, when applied to our patient data set, unsupervised techniques elucidate underlying novel subgroups of infant leukemia cases. In turn, this reassessment of tumor heterogeneity encourages the design of additional studies to ascertain whether these data can enhance the discriminatory power of currently employed prognostic variables.

Heterogeneous distribution of the MLL cases

The most common mutations in infant leukemia are translocations of the *MLL* gene at chromosome band 11q23. Interestingly, the *MLL* cases in cluster A (Fig. 10, lower left panel) are primarily t(4;11) (n=7), as well as two cases with t(10;11) and one with t(11;19). Cluster B, composed of virtually entirely ALL cases, contains a large number of t(4; 11) cases (n=29) as well as four cases with t(11;19), one case of t(10;11), and one case of t(1;11). Finally, the bottom right cluster (n=54),

predominantly AML but containing twelve cases with an ALL label that nonetheless have more "myeloid" patterns of gene expression, also comprises five cases with t(9;11), three cases with t(1;11), three cases with t(11;19), one case with t(4;11) and three cases with other MLL translocations.

5 *MLL* cases with the same translocation (t(4;11) in clusters A and B) had dramatic differences in their gene expression profiles. The mechanisms that might underlie this striking difference are currently under study. Genes that have common patterns in the *MLL* cases across all three clusters have been identified; as well as genes that are uniquely expressed and which distinguish each *MLL* translocation
10 variant. Although *MLL* cases are not homogeneous, it is interesting that the list of statistically significant genes derived in this study is quite similar to the list of genes derived by previous groups working in infant *MLL* leukemia (Armstrong, 2002). For reasons not understood, infants are more prone to *MLL* rearrangements that inhibit apoptosis and cause transformation. (reviewed in Van Limbergen et al, 2002). Our
15 results suggest that the *MLL* translocation in these patients may not be the "initiating" event in leukemogenesis. It is possible that after a distinct initiating event, the infant patient is more prone to rearrange the *MLL* gene, and that this rearrangement leads to further cell transformation by preventing apoptosis. Alternatively, an *MLL*
20 translocation could be a permissive initiating event with leukemogenesis and final gene expression profile determined more strongly by second mutations. Further studies within the *MLL* group of infant leukemia patients may provide the clues to processes determinant in leukemic transformation.

Pathways to failure in infant leukemia

25 In general, gene expression data has supported the existence of several categories of acute leukemias related to the traditionally defined leukemia types, ALL and AML (Golub, 1999; Moos, 2002). However, while expression profiling is a robust approach for the accurate identification of known lineage and molecular subtypes across acute leukemia cases, the search for clinically relevant prognosis
30 discriminators based on gene expression patterns has been less successful (Armstrong, 2002; Ferrando, 2002; Yeoh, 2002). As shown in Table 46, only SVM-RFE was able to identify remission vs. failure across the unconditioned data set with a total error rate differing from random prediction (success rate of 64% at a significance level of $p < 0.1$). Interestingly, the performance of our outcome classification algorithms was

not increased when conditioned on either of the traditional criterion of lineage (ALL vs. AML) nor cytogenetics (*MLL* vs. not *MLL*), providing further support for questioning the predictive value of these traditional clinical labels in explaining outcome in infant patients. However, far greater success in outcome prediction is obtained when conditioning the classifying algorithms on the VxInsight cluster membership. The effect of the three VxInsight clusters on our ability to predict remission vs. failure was then explored. In particular, we attempted to predict remission vs. failure in the entire data set, conditioned on the knowledge of into which VxInsight cluster each case falls. The hope was that, by utilizing knowledge of VxInsight cluster membership, inter-cluster expression profile variability of cases - which is not necessarily relevant to outcome prediction- would be eliminated, allowing intra-cluster variability relevant to outcome prediction to be more easily discovered by our classification algorithms.

Table 46 demonstrates that prediction accuracy is gained by coupling the supervised learning algorithms with VxInsight clustering. In the Bayesian method, accuracy against the test set rises from 0.568 ($p=0.256$) to 0.703 ($p=0.010$). Smaller improvements after conditioning are found with the other methods as well. One can look also at the prediction accuracy within the VxInsight clusters individually. There again a general rise in accuracy is observed, though not to a level of statistical significance, possibly due to the small size and/or class balance of the individual clusters.

We note that, from the more abstract perspective of machine learning theory, the construction of the VxInsight clusters is viewed as an external feature creation algorithm that is applied to a data set before the supervised learning algorithms begin their training. In the application at hand, the created feature is 3-valued, indicating membership of a case in VxInsight cluster A, B, or C. This feature creation process is akin to the pre-selection of features, based on measures of information content, that is employed by many supervised learning algorithms when run on problems of high dimensionality. One difference between the VxInsight feature creation step and traditional feature selection is that VxInsight clustering is performed without knowledge of the class label to be predicted (outcome, in this context), and hence it is reasonable to perform the clustering on the entire data set (train and test sets combined) at once.

The relative strength of the gene lists and parent sets can be thought of as being correlated with the prediction accuracy within the corresponding VxInsight cluster. However, it is the application of the lists and parent sets together within the two-step VxInsight / supervised learning conditioning framework described above
5 that achieves statistical significance in its accuracy.

It is rather unlikely that random chance alone would improve such accuracy levels, since a process independent of the best error rate generated the VxInsight clustering. These results are taken as strong evidence that the VxInsight patient clusters reflect biologically important groups and, are clinically exploitable. In
10 contrast, comparable accuracy was not achieved by conditioning on either of the traditional criteria of ALL vs. AML, nor *MLL* vs. not *MLL*. This may indicate that, as determined by our molecular analysis, these traditional clinical criteria for segregating treatment cohorts are less defining than has been supposed.

Table 47 illustrates the resulting set of distinguishing genes associated with
15 remission/failure in the overall data set (not partitioning by type, cytogenetics or cluster), which represent potentially important diagnostic and therapeutic targets. Some of these outcome-correlated genes include Smurf1, a new member of the family of E3 ubiquitin ligases. Smurf1 selectively interacts with receptor-regulated MADs (mothers against decapentaplegia-related proteins) specific for the BMP pathway in
20 order to trigger their ubiquitination and degradation, and hence their inactivation. Targeted ubiquitination of SMADs may serve to control both embryonic development and a wide variety of cellular responses to TGF- β signals. (Zhu, 1999). Another interesting gene is the SMA- and MAD-related protein, SMAD5, which plays a critical role in the signaling pathway in the TGF- β inhibition of proliferation of
25 human hematopoietic progenitor cells (Bruno, 1998). The list also included regulators of differentiation and development; bone morphogenetic 2 protein, member of the transforming growth factor-beta (TGF- β) super family and determinant in neural development (White, 2001); DYRK1, a dual-specificity protein kinase involved in brain development (Becker, 1998); a small inducible cytokine A5 (SCYA5), the T cell
30 activation increased late expression (TACTILE), and a myeloid cell nuclear differentiation antigen (MNDA). It is remarkable that this list includes potential diagnostic or therapeutic targets like the ERG oncogene (V-ETS Avian Erythroblastosis virus E26 oncogene related, found in AML patients), the phospholipase C-like protein 1 (PLCL, tumor suppressor gene), a cystein rich

angiogenic inducer (CYR61), and the MYC, MYB oncogenes. Other genes in the list are located in critical regions mutated in leukemia, which suggests their connection with the leukemogenic process. Such genes include Selenoprotein P (SPP1, 5q), the protein kinase inhibitor p58 (DNAJC3 in 13q32), and the cyclin C (CCNC).

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Discussion

Traditionally, infant leukemia has been classified according to a host of clinical parameters and biological features that tend to correlate with prognosis. This classification system has been used for risk-based classification assignment. However, unexplained variability in clinical courses still exists among some individuals within defined risk-group strata. Differences in the molecular constitution of malignant cells within subgroups may help to explain this variability.

In our initial profiling of 126 infant acute leukemia cases, we have used microarray technology to both segregate patient subgroups and to uncover genetic diversity among patients that fall within the same traditional risk groups. The results reported here identify three previously unrecognized groups of infant leukemia cases, driven by differential gene expression pattern and possibly related to three independent disease initiation mechanisms. Two of these clusters support previous data about leukemic etiology: environmental exposure and viral infections, both of which may occur in utero.

Our data also supports the existence of a third group, with a particular gene expression pattern suggestive of a novel stem cell neoplasia with leukemic behavior. The genes expressed in most of these cases resemble those present in the hematopoietic/angioblastic primordial cell (Young, 1995; Eichman, 1997); see for example, Figs. 11 and 12. This subgroup may be therapeutically relevant and may also provide additional evidence for the existence of a common progenitor, possibly the primordial hematopoietic/endothelial cell. The gene expression blueprint of this cluster seems to characterize a unique and distinct subclass of infant leukemia that represents transformed, true multi-potent stem cells or "cancer stem cells". There is an important body of work suggesting that normal hematopoietic stem cells may be target of transforming mutations and that cancer cell proliferation is driven by cancer stem cells (Reya, 2001). Our data provides further evidence in support of the hypothesis that newly arising cancer cells may appropriate the machinery for self-renewing cell divisions, which is normally expressed in stem cells.

Together, these results indicate the occurrence of, at least, three inherent biological subgroups of infant leukemia, not precisely defined by traditional AML vs. ALL or cytogenetics labels; probably driven by characteristics with potential clinical relevance. Consideration of these three categories may enable selection criteria for more powerful clinical trials, and might lead to improved treatments with better success rates.

METHODS

To develop gene expression-based classification schemes related to the pathogenic basis underlying the leukemic process in infant acute leukemia, 126 patients registered to NCI-sponsored Infant Oncology Group/Children's Oncology Group treatment trials were examined using Affymetrix U95Av2 oligonucleotide microarrays containing 12,625 probes. Of the 126 cases, 78 were ALL (62%), 48 were AML (38%) and 56 (44%) cases had translocations involving the *MLL* gene (chromosome segment 11q23). An average of 2×10^7 cells were used for total RNA extraction with the Qiagen RNeasy mini kit (Valencia, CA). The yield and integrity of the purified total RNA were assessed with the RiboGreen assay (Molecular Probes, Eugene, OR) and the RNA 6000 Nano Chip (Agilent Technologies, Palo Alto, CA), respectively. Complementary RNA (cRNA) target was prepared from 2.5 µg total RNA using two rounds of Reverse Transcription (RT) and In Vitro Transcription (IVT). Following denaturation for 5 minutes at 70°C, the total RNA was mixed with 100 pmol T7- (dT) ₂₄ oligonucleotide primer (Genset Oligos, La Jolla, CA) and allowed to anneal at 42°C. The mRNA was reverse transcribed with 200 units Superscript II (Invitrogen, Grand Island, NY) for 1 hour at 42°C. After RT, 0.2 vol. 5X second strand buffer, additional dNTP, 40 units DNA polymerase I, 10 units DNA ligase, 2 units RnaseH (Invitrogen) were added and second strand cDNA synthesis was performed for 2 hours at 16°C. After T4 DNA polymerase (10 units), the mix was incubated an additional 10 minutes at 16°C. An equal volume of phenol:chloroform:isoamyl alcohol (25:24:1) (Sigma, St. Louis, MO) was used for enzyme removal. The aqueous phase was transferred to a microconcentrator (Microcon 50. Millipore, Bedford, MA) and washed/concentrated with 0.5 ml DEPC water twice the sample was concentrated to 10-20µl. The cDNA was then transcribed with T7 RNA polymerase (Megascript, Ambion, Austin, TX) for 4 hours at 37°C.

Following IVT, the sample was phenol:chloroform:isoamyl alcohol extracted, washed and concentrated to 10-20 μ l. The first round product was used for a second round of amplification which utilized random hexamer and T7- (dT)₂₄ oligonucleotide primers, Superscript II, two RNase H additions, DNA polymerase I plus T4 DNA polymerase finally and a biotin-labeling high yield T7 RNA polymerase kit (Enzo Diagnostics, Farmingdale, NY). The biotin-labeled cRNA was purified on Qiagen RNeasy mini kit columns, eluted with 50 μ l of 45°C RNase-free water and quantified using the RiboGreen assay. Following quality check on Agilent Nano 900 Chips, 15 μ g cRNA were fragmented following the Affymetrix protocol (Affymetrix, Santa Clara, CA). The fragmented RNA was then hybridized for 20 hours at 45°C to HG_U95Av2 probes. The hybridized probe arrays were washed and stained with the EukGE_WS2 fluidics protocol (Affymetrix), including streptavidin phycoerythrin conjugate (SAPE, Molecular Probes, Eugene, OR) and an antibody amplification step (Anti-streptavidin, biotinylated, Vector Labs, Burlingame, CA). HG_U95Av2 chips were scanned at 488 nm, as recommended by Affymetrix. The expression value of each gene was calculated using Affymetrix Microarray Suite 5.0 software.

Data Presentation and Exclusion Criteria

Some of the criteria used as quality controls include: total RNA integrity, cRNA quality, array image inspection, B2 oligo performance, and internal control genes (GAPDH value greater than 1800).

Data Analysis

Affymetrix MAS 5.0 statistical analysis software was used to process the raw microarray image data for a given sample into quantitative signal values and associated present, absent or marginal calls for each probeset. A filter was then applied which excluded from further analysis all Affymetrix "control" genes (probesets labeled with AFFY_ prefix), as well as any probeset that did not have a "present" call at least in one of the samples. For this analysis our Bayesian classification and VxInsight clustering analysis omitted this step, choosing instead to assume minimal *a priori* gene selection (Helman et al, 2003; Davidson *et al.*, 2001). The filtering step reduced the number of probe sets from 12,625 to 8,414, resulting in a matrix of 8,414 x *N* signal values, where *N* is the number of cases. The first stage of

our analysis consisted of a series of binary classification problems defined on the basis of clinical and biologic labels. The nominal class distinctions were ALL/AML, MLL/not-MLL, achieved complete remission CR/not-CR. Additionally, several derived classification problems—based on restrictions of the full cohort to particular subsets of data such as a VxInsight cluster—were considered (see main text). The multivariate unsupervised learning techniques used included Bayesian nets (Helman *et al.*, 2003) and support vector machines (Guyon *et al.*, 2002). The performance of the derived classification algorithms was evaluated using fold-dependent leave-one-out cross validation (LOOCV) techniques. These methods combined allowed the identification of genes associated with remission or treatment failure and with the presence or absence of translocations of the MLL gene across the dataset.

In order to identify potential clusters and inherent biologic groups, a large number of clinical co-variables were correlated with the expression data using unsupervised clustering methods such as hierarchical clustering, principal component analysis and a force-directed clustering algorithm coupled with the VxInsight visualization tool.

Agglomerative hierarchical clustering with average linkage (similar to Eisen *et al.*, 1998) was performed with respect to both genes and samples, using the MATLAB (The Mathworks, Inc.), the MatArray toolbox and native MATLAB statistics toolbox.

The data for a given gene was first normalized by subtracting the mean expression value computed across all patients, and dividing by the standard deviation across all patients for each gene. The distance metric used was one minus Pearson's correlation coefficient; this choice enabled subsequent direct comparison with the VxInsight cluster analysis, which is based on the *t*-statistic transformation of the correlation coefficient (Davidson *et al.*, 2001). The second clustering method was a particle-

based algorithm implemented within the VxInsight knowledge visualization tool (www.sandia.gov/projects/VxInsight.html). In this approach, a matrix of pair similarities is first computed for all combinations of patient samples. The pair similarities are given by the *t*-statistic transformation of the correlation coefficient determined from the normalized expression signatures of the samples (Davidson *et al.*, 2001). The program then randomly assigns patient samples to locations (vertices) on a 2D graph, and draws lines (edges), thus linking each sample pair, and assigning each edge a weight corresponding to the pairwise *t*-statistic of the correlation. The resulting 2D graph constitutes a candidate clustering. To determine the optimal clustering, an iterative annealing procedure is followed, wherein a 'potential energy'

function that depends on edge distances and weights is minimized, following random moves of the vertices (Davidson *et al.*, 1998, 2001). Once the 2D graph has converged to a minimum energy configuration, the clustering defined by the graph is visualized as a 3D terrain map, where the vertical axis corresponds to the density of samples located in a given 2D region. The resulting clusters are robust with respect to random starting points and to the addition of noise to the similarity matrix, evaluated through its effect on neighbor stability histograms (Davidson *et al.*, 2001).

REFERENCES

- Alizadeh, A. A., Eisen, M. B., Davis, R. E., *et al.* Distinct types of diffuse large B-cell lymphoma identified by gene expression profiling. *Nature* 403, 503-511 (2000).
- Akashi, K., He, X., Chen, J., Iwasaki, H., Niu, C., Steenhard, B., Zhang, J., Haug, J., Li, L. Transcriptional accessibility for genes of multiple tissues and hematopoietic lineages is hierarchically controlled during early hematopoiesis. *Blood* 101, 383-90 (2003).
- Armstrong, S. A., Staunton, J. E., Silverman, L. B., *et al.* MLL translocations specify a distinct gene expression profile that distinguishes a unique leukemia. *Nature Genetics* 30, 41-47 (2002).
- Birkenbach, M., Josefsen, K., Yalamanchili, R., Lenoir, G., Kieff, E. Epstein-Barr virus-induced genes: first lymphocyte-specific G protein-coupled peptide receptors. *J Virol* 67, 2209-20 (1993).
- Davidson, G. S., Wylie, B. N., and Boyack, K. W. Cluster stability and the use of noise in interpretation of clustering. *Proc. IEEE Information Visualization 2001*, 23-30 (2001).
- Davidson, G. S., Hendrickson, B., Johnson, D. K., Meyers, C. E., & Wylie, B. N. Knowledge mining with VxInsight: Discovery through interaction. *J. Int. Inf. Syst.* 11, 259-285 (1998).

Eichmann, A., Corbel, C., Nataf, V., Vaigot, P., Breant, C. and Le Douarin, N.M. Ligand dependent development of the endothelial and hepatopoietic lineages from embryonic mesodermal cells expressing vascular endothelial growth factor receptor 2. *Proc. Natl. Acad. Sci. U.S.A.* 94, 5141-5146 (1997).

5

Eisen, M. B., Spellman, P. T., Brown, P. O., and Botstein, D. Cluster analysis and display of genome-wide expression patterns. *Proc. Natl. Acad. Sci. USA* 95, 14863-14868 (1998).

10 Efron, B. Bootstrap methods—"another look at the jackknife" *Ann. Statist.*,7, 1-26 (1979).

Golub TR, Slonim DK, Tamayo P, Huard C, Gaasenbeek M, Mesirov JP, Coller H, Loh ML, Downing JR, Caligiuri MA, Bloomfield CD, Lander ES. Molecular
15 classification of cancer: class discovery and class prediction by gene expression monitoring. *Science* 286, 531-7 (1999).

Guyon I, Weston, J, Barnhill S, and Vapnik V. Gene Selection for Cancer
Classification Using Support Vector Machines. *Machine Learning* 46, 389-422
20 (2002).

Helman P, Veroff R, Atlas S, and Willman CL. A new Bayesian network
classification methodology for gene expression data. *Journal of Computational
Biology*, submitted (2002); available on the worldwide web at
25 cs.unm.edu/~helman/papers/JCB_Total.pdf.

Hjorth, J.S. *Urban Computer Intensive Statistical Methods, Validation model selection and bootstrap*, ISBN 0412491605, Chapman & Hall, 2-6 Boundary Row, London
SE1 8HN, UK. (1994).

30

Jolliffe, I.T. *Principal Component Analysis*. Springer-Verlag (1986).

Khan, J., Wei, J. S., Ringnér, M., Saal, L. H., Ladanyi, M., Westermann, F., Berthold, F., Schwab, M., Antonescu, C. R., Peterson, C., and Meltzer, P. S. Classification and

diagnostic prediction of cancers using gene expression profiling and artificial neural networks. *Nature Medicine* 7, 673 (2001).

- Kim, S. K., Lund, J., Kiraly, M., Duke, K., Jiang, M., Stuart, J. M., Eizinger, A.,
5 Wylie, B. N., and Davidson, G. S. A gene expression map for *Caenorhabditis elegans*. *Science* 293, 2087-2092 (2001).

Kirby, M. Geometric Data Analysis. John Wiley & Sons (2001).

- 10 Oklu, R., Hesketh, R. The latent transforming growth factor b binding protein (LTBP) family. *Biochem. J.* 352, 601–610 (2000) Review

- Ramaswamy, S., Tamayo, P., Rifkin, R., Mukherjee, S., Yeang, C.-H., Angelo, M.,
Ladd, C., Reich, M., Latulippe, E., Mesirov, J. P., Poggio, T., Gerald, W., Loda, M.,
15 Lander, E. S., and Golub, T. R. Multiclass cancer diagnosis using tumor gene expression signatures. *Proc. Natl. Acad. Sci. USA* 98, 15149 (2001).

- Raychaudhuri, S., Stuart, J., and Altman, R. Principal component analysis to summarize microarray experiments: application to sporulation time series. *Pac. Symp. Biocomput.*, 5, 455-466 (2000).
20

- Rosenwald, A., Wright, G., Chan, W.C., Connors, J. M., Campo, E., Fisher, R. I., Gascoyne, R.D., Muller-Hermelink, H.K., Smeland, E.B., and Staudt, L. M. The use of molecular profiling to predict survival after chemotherapy for diffuse large-B-cell
25 lymphoma. *N. Engl. J. Med.* 346, 1937 (2002).

Skalnik DG. Transcriptional mechanisms regulating myeloid-specific genes. *Gene* 284,1-21(2002).

- 30 Staeger, M.S., Lee, S.P., Frisan, T., Maunter, J., Scholz, S., Pajic, A., Rickinson, A.B., Masucci, M.G., Polack, A., Bornkamm, G.W. MYC overexpression imposes a nonimmunogenic phenotype on Epstein-Barr virus-infected B cells. *Proc. Natl. Acad. Sci. USA.* 99, 4550-4555 (2002).

Tamayo, P., Slonim, D., Merisov, J., Zhu, Q., Kitareewan, S., Dimitrovsky, E., Lander, E., Golub, T. Interpreting patterns of gene expression with self-organizing maps: Methods and application to hematopoietic differentiation. *Proc. Natl. Acad. Sci.*, 96, 2907-2912 (1999).

5

Trefethen, L. & Bau, D. *Numerical Linear Algebra*. SIAM, Philadelphia (1997).

van 't Veer, L. J., Dal, H., van de Vijver, M. J., *et al.* Gene expression profiling predicts clinical outcome of breast cancer. *Nature* 415, 530-536 (2002).

10

Werner-Washburne, M., Wylie, B., Boyack, K., Fuge, E., Galbraith, J., Fleharty, M., Weber, J., Davidson, G.S. Concurrent analysis of multiple genome-scale datasets. *Genome Research* (12), 1564-1573, 2002

15 Young, P.E., Baumhueter, S. and Laskiy, L.A. The sialomucin CD34 is expressed on hematopoietic cells and blood vessels during murine development. *Blood*, 85, 96-105 (1995).

Table 44. Class Predictor Performance

Description	Bayesian Net			SVM			Fuzzy Inference			Discriminant Analysis		
	r	p-value ¹	p-value ²	r	p-value ¹	p-value ²	r	p-value ¹	p-value ²	r	p-value ¹	p-value ²
ALL vs. AML	.912	<.001**	<.001**	.971	<.001**	<.001**	.971	<.001**	<.001**	.853	<.001**	<.001**
t(4;11) vs. Not t(4;11)	.818	<.001**	.005**	.879	<.001**	<.001**	.788	<.001**	.021*	.788	<.001**	.022*
Remission. vs. Fail	.568	.256	.507	.622	.094	-----	.405	.906	.997	.568	.256	.507

Table 44. Class Predictor Performance In order to optimize gene selection and determine the success rate of each classifier, fold-

5 dependent leave-one-out cross-validation was used on the training set (n=82) followed by "single shot" prediction on our validation set (n=44) using the trained classifiers. r = Success rate; $p\text{-value}^1$ = Computed using the first method as described in Supplemental Information; $p\text{-value}^2$ = Computed using the second method as described in Supplemental Information.

* means that the predictor is significant at level $\alpha=0.05$

** means that the predictor is significant at level $\alpha=0.01$.

10 ----- indicates that the Fisher's exact test can not be fulfilled because two cells in the contingency table are zero.

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Table 45. Genes with differential expression patterns between the *VxInsight* clusters A and the rest of the cases. The gene lists are sorted into decreasing order based on the resulting F-scores.

Cluster A – Up-regulated genes				
F score symbol	p	Affymetrix number	Gene description	Gene
167.99	0.001	37746_r_at	Tumor suppressor gene	TS5
124.38	0.005	36276_at	Contactin 2 axonal	CNTN2
123.10	0.006	33058_at	Cytokeratin type II	K6HF
122.51	0.010	33137_at	Transforming growth factor beta binding protein 4	LTBP4
119.66	0.004	721_g_at	Heat-shock transcription factor 4	HSF4
114.94	0.019	396_f_at	Erythropoietin receptor precursor	EPOR
114.21	0.011	41565_at	Ataxin 2 related protein	A2LP
113.20	0.007	40792_s_at	Triple functional domain interacting	PTPRF
109.97	0.008	884_at	Integrin α 3	ITGA3
98.55	0.010	40539_at	Myosin IXB	MYO9B
98.43	0.040	41694_at	Temperature sensitivity complementing	BHK21
94.32	0.020	41347_at	p70 ribosomal S6 kinase beta (iroquois homeobox protein 5)	IRX5
92.02	0.010	38132_at	Serum constituent protein	MSE55
88.80	0.021	39448_r_at	B7 protein	B7
85.44	0.035	34573_at	Ephrin A3	EFNA3
84.99	0.020	34894_r_at	Protease serine 26	PRSS22
82.83	0.029	39775_at	Complement component inhibitor 1	SERPING1
82.51	0.031	41499_at	v-ski avian sarcoma viral oncogene	SKI
80.85	0.010	567_s_at	Promyelocytic leukemia	PML
77.97	0.020	38707_r_at	E2F transcription factor 4	E2F4
76.97	0.044	37061_at	Chitotriosidase	CHIT1
73.43	0.021	1804_at	Kallikrein 3 prostate specific antigen	KLK3
73.74	0.041	38058_at	Dermatopontin precursor	DPT
72.07	0.023	39868_at	poly rC binding protein 3	PCBP3
72.48	0.033	35910_f_at	Zinc finger protein 200 (matrix metalloproteinase like)	MMPL
69.03	0.041	39920_r_at	C1q-related factor	CRF
68.53	0.051	37140_s_at	Ectodermal dysplasia 1 anhidrotic	ED1

68.52	0.055	39306_at	Protease serine 16 thymus	PRSS16
68.07	0.062	1925_at	Cyclin F	CCNF
67.57	0.093	40501_s_at	Myosin-binding protein C slow-type	MYBPC1
66.62	0.052	160020_at	Matrix metalloproteinase 14 preprotein	MMP14
63.85	0.043	33448_at	Hepatocyte growth factor activator inhibitor precursor	SPINT1
62.14	0.035	33034_at	Rhomboid veinlet Drosophila like	RHBDL
61.86	0.055	31393_r_at	Undifferentiated embryonic cell	UTF1
			transcription factor 1	
61.28	0.039	41359_at	Plakophilin 3	PKP3
60.51	0.103	538_at	CD34 antigen	CD34

Table 45. Continuation. Genes with differential expression patterns between the *VxInsight* clusters A and the rest of the cases.

Cluster A – Down-regulated genes

F score symbol	p	Affymetrix number	Gene description	Gene
115.50	0.018	36991_at	Splicing factor arginine/serine-rich 4	SFRS4
114.41	0.015	1241_at	protein tyrosine phosphatase type IVA member 2	PTP4A
108.68	0.013	41187_at	death-associated protein 6	DAXX
98.82	0.018	37675_at	phosphate carrier precursor 1b	PHC
95.63	0.026	37029_at	ATP synthase H transporting mitochondrial F1 complex O subunit	ATP50
95.11	0.019	41834_g_at	jumping translocation breakpoint	JTB
94.08	0.027	41295_at	GTT1 protein	GTT1
92.64	0.027	1817_at	prefoldin 5	PFDN5
90.62	0.029	35279_at	Tax1 human T-cell leukemia virus type I binding protein 1	TAX1BP1
90.18	0.027	32832_at	erythroblast macrophage attacher	No symbol
87.74	0.028	1357_at	ubiquitin specific protease proto-oncogene	USP4
87.26	0.047	1499_at	farnesyltransferase CAAX box alpha	FNTA

84.12	0.048	37766_s_at	proteasome prosome macropain 26S subunit ATPase 5	PSMC5
83.23	0.056	1399_at	elongin C	TCEB1
82.82	0.042	41241_at	asparaginyl-tRNA synthetase	NARS
78.67	0.030	36492_at	proteasome prosome macropain 26S subunit non-ATPase 9	PSMD9
78.21	0.043	37581_at	protein phosphatase 6 catalytic subunit	PPP6C
78.18	0.082	39360_at	sorting nexin 3	No symbol
76.07	0.054	36616_at	DAZ associated protein 2	No symbol
75.21	0.063	34330_at	cytochrome c oxidase subunit VIIa polypeptide 2 like	COX7A2L
74.72	0.044	31670_s_at	calcium/calmodulin-dependent protein kinase CaM kinase II gamma	CAMKG
74.30	0.045	39184_at	elongin B	TCEB2
73.46	0.055	34302_at	eukaryotic translation initiation factor 3 subunit 4 delta 44kD	EIF3S4
72.24	0.074	35298_at	eukaryotic translation initiation factor 3 subunit 7 zeta 66/67kD	EIF3S7
71.36	0.055	41551_at	similar to S. cerevisiae RER1	No symbol
71.28	0.057	35297_at	NADH dehydrogenase ubiquinone 1 alpha/beta subcomplex 1 8kD SDAP	NDUFAB1
71.06	0.059	40874_at	endothelial differentiation-related 1	EDF1
70.73	0.045	38455_at	small nuclear ribonucleoprotein polypeptides B and B1	SNRPB
69.57	0.082	935_at	adenylyl cyclase-associated protein	No symbol
69.09	0.077	31492_at	muscle specific gene	No symbol
68.81	0.043	37672_at	ubiquitin specific protease 7 herpes virus-associated	USP7
68.31	0.066	35319_at	CCCTC-binding factor zinc finger protein	CTCF

Table 45. Continuation. Genes with differential expression patterns between the *VxInsight* cluster B and the rest of the cases.

Cluster B – Up-regulated genes				
F score symbol	p	Affymetrix number	Gene description	Gene
250.55	0.001	40103_at	Villin 2	VIL2

157.12	0.003	1096_g_at	CD19 antigen	CD19
122.41	0.005	38269_at	Protein kinase D2	PKD2
113.79	0.005	2047_s_at	Junction plakoglobin isoform 1	JUP
113.35	0.006	35298_at	Eukariotic translation initiation factor 3	EIF3
109.78	0.010	36991_at	Splicing factor arg/ser rich 4	SFRS4
107.87	0.011	854_at	B lymphoid tyrosine kinase	BLK
105.40	0.005	41356_at	B-cell CLL/lymphoma 11A	BCL11A
101.07	0.006	38017_at	CD79A antigen	CD79A
91.63	0.010	37672_at	Ubiquitin specific protease 7 herpes virus associated	USP7
91.08	0.020	37585_at	Small nuclear ribonucleotide polypeptide A	SNRPA1
89.36	0.023	31492_at	Muscle specific gene	M9
87.23	0.008	36111_s_at	Splicing factor arg/ser rich 2	SFRS2
85.38	0.041	1754_at	Death associated protein	DAXX
81.74	0.039	1357_at	Ubiquitin specific protease proto-oncogene	USP
74.04	0.047	41834_g_at	Jumping translocation breakpoint	JTB
73.16	0.020	39044_s_at	Diacylglycerol kinase delta	DGKD
73.14	0.013	38604_at	Neuropeptide Y	NPY
71.06	0.010	32238_at	Binding integrator 1	BIN1
70.78	0.031	38054_at	Hepatitis B virus interacting x-protein	HBXIP
68.13	0.050	1817_at	Prefoldin 5	PFDN5
67.74	0.018	32842_at	B-cell CLL/lymphoma	BCL2
63.71	0.069	40189_at	SET translocation myeloid-leukemia associated	SET
61.60	0.015	33304_at	Interferon stimulated gene 20kD	ISG20
59.35	0.025	38989_at	DC 12 protein	DC12
57.53	0.045	36630_at	Delta sleep inducing petide	DSIP1
56.43	0.035	36949_at	Casein kinase 1 delta	CSNK1D
56.22	0.027	1814_at	Transforming growth factor beta receptor	TGFBR2
56.07	0.031	39318_at	T-cell lymphoma-1	TCL1A
54.40	0.037	37028_at	DNA damage inducible	PPP1R15A
53.94	0.021	1102_s_at	Nuclear receptor subfamily 3 group C	NR3C1
51.74	0.033	40828_at	PAK-interacting exchange factor beta	ARHGEF7
51.32	0.025	493_at	Casein kinase 1 delta	CSNK1D
50.93	0.039	40365_at	Guanine nucleotide binding protein G	GNA15
50.77	0.037	32070_at	Tyrosin phosphatase receptor type	PTPRCAP

50.59	0.054	35974_at	Lymphoid-restricted membrane protein	LRMP
50.37	0.048	34180_at	Rho guanine nucleotide exchange factor	GEF10
50.06	0.031	280_g_at	Nuclear receptor subfamily 4 group A1	NR4A1
48.15	0.017	41203_at	Zinc finger protein 162 (splice factor1)	SF1
47.98	0.030	40841_at	Transforming acidic coiled-coil	TACC1

Table 45. Continuation. Genes with differential expression patterns between the *VxInsight* cluster B and the rest of the cases.

Cluster B – Down-regulated genes				
F score symbol	p	Affymetrix number	Gene description	Gene
81.4	0.007	39689_at	cystatin C amyloid angiopathy	CST3
78.48	0.004	36938_at	N-acylsphingosine amidohydrolase acid ceramidase	ASAH
67	0.011	1230_g_at	cisplatin resistance associated	No symbol
57.88	0.022	34885_at	synaptogyrin 2	SYNGR2
57.26	0.018	35367_at	lectin galactoside-binding soluble 3 galectin 3	LGALS3
54.71	0.015	36766_at	ribonuclease RNase A family 2 liver eosinophil-derived neurotoxin	RNASE2
52.66	0.029	32747_at	aldehyde dehydrogenase 2 family mitochondrial	ALDH2
51.51	0.022	36879_at	endothelial cell growth factor 1 platelet-derived	ECGF1
51.32	0.021	39994_at	chemokine C-C motif receptor 1	CCR1
50.88	0.014	35012_at	myeloid cell nuclear differentiation antigen	MNDA
50.53	0.02	36889_at	Fc fragment of IgE high affinity I receptor for gamma polypeptide precursor	FCER1G
50.41	0.023	34789_at	serine or cysteine proteinase inhibitor clade B ovalbumin member 6	PIR6
50.21	0.029	1052_s_at	CCAAT/enhancer binding protein C/EBP delta	CEBPD
49.91	0.014	37398_at	platelet/endothelial cell adhesion molecule CD31 antigen	CD31
49.79	0.022	40580_r_at	parathymosin	PTMS

47.39	0.03	41096_at	S100 calcium-binding protein A8	S100A8
47.26	0.031	33963_at	azurocidin 1 cationic antimicrobial protein 37	No symbol
47.06	0.018	36465_at	interferon regulatory factor 5	No symbol
46.95	0.03	37021_at	cathepsin H	CTSH
46.36	0.029	35926_s_at	leukocyte immunoglobulin-like receptor subfamily B with TM and ITIM domains	No symbol
46.02	0.02	41523_at	RAB32 member RAS oncogene family	RAB32
45.94	0.034	38363_at	TYRO protein tyrosine kinase binding protein	TYROBP
44.74	0.032	33856_at	CAAX box 1	CXX1
44.73	0.038	40282_s_at	adipsin/complement factor D precursor	DF
44.5	0.027	32451_at	membrane-spanning 4-domains subfamily A member 3 hematopoietic cell-specific	No symbol
44.08	0.045	38631_at	tumor necrosis factor alpha-induced protein 2	TNFAIP2
44.01	0.053	40762_g_at	solute carrier family 16 monocarboxylic acid transporters member 5	SLC16A5

Table 45. Continuation. Genes with differential expression patterns between the *VxInsight* cluster C and the rest of the cases.

Cluster C – Up-regulated genes				
F score symbol	p	Affymetrix number	Gene description	Gene
284.97	0.001	6938_at	N-acylsphingosine aidohydrolase acid ceramidase	ASAH
132.03	0.001	9689_at	Cystatin C	CST3
126.67	0.013	1637_at	Mitogen-activated protein kinase-activated protein kinase 3	MAPKAPK3
114.85	0.010	38363_at	Tyro Protein tyrosine kinase binding protein	TYROBP
104.53	0.009	35297_at	NADH dehydrogenase ubiquinone 1	NDUFAB1
100.84	0.008	1230_g_at	Cisplatin resistance associated	
93.33	0.008	36879_at	Endothelial cell growth factor 1 – platelet derived	ECGF1
90.92	0.009	3856_at	Farnesyltransferase CAAX box alpha	FNTA

89.47	0.017	35279_at	Tax1 human T-cell leukemia virus type I TAX1BP1 binding protein I	
88.39	0.047	39160_at	Pyruvate dehydrogenase lipoamide beta	PDHB
84.75	0.036	41187_at	Death-associated protein 6	DAP6
84.18	0.029	41495_at	GTT1 protein	GTT1
81.31	0.006	41523_at	RAB32 member RAS oncogene family	RAB32
80.08	0.048	37337_at	Small nuclear ribonucleoprotein G	SNRPG
75.51	0.038	402_s_at	Intercellular adhesion molecule	ICAM3
74.82	0.014	40282_s_at	Adipsin/complement factor D	DF
72.20	0.050	39360_at	Sortin nexin 3	SNX3
70.26	0.055	37726_at	Mitochondrial ribosomal protein L3	MRPL3
69.05	0.016	39581_at	Cystatin A (stefin A)	CSTA
68.66	0.035	1817_at	Prefoldin 5	PFDN5
67.80	0.059	36620_at	Superoxide dismutase 1 soluble	SOD1
66.34	0.090	37670_at	Annexin VII	ANXA7
65.36	0.065	38097_at	Etoposide-induced mRNA	PIG8
65.07	0.092	824_at	Glutathione-S-transferase like	GSTTLp28
64.88	0.016	39593_at	Similar to fibrinogen-like 2, clone MGC:22391, mRNA, complete cds	
63.75	0.024	35012_at	Myeloid cell nuclear differentiation	MNDA
63.30	0.047	1399_at	Elongin C	TCEB1
62.02	0.079	891_at	YY1 transcription factor	YY1
61.60	0.079	38992_at	DEK oncogene DNA binding	DEK
54.78	0.036	37021_at	Cathepsin H	CTSH
54.28	0.029	41198_at	Granulin	GRN
54.27	0.028	38631_at	Tumor necrosis factor alpha-induced protein 2	TNFAIP2
54.26	0.032	34860_g_at	Melanoma antigen, family D, 2	MAGED2
52.80	0.037	1693_s_at	Tissue inhibitor of metalloprotease 1	TIMP1
48.83	0.031	38533_s_at	Integrin alpha M precursor	ITGAM
48.64	0.038	36709_at	Integrin alpha X precursor	ITGAX
48.37	0.021	34885_at	Synaptogyrin 2	SYNGR2

Table 45. Continuation. Genes with differential expression patterns between the *VxInsight* cluster C and the rest of the cases.

Cluster C – Down-regulated genes				
F score symbol	p	Affymetrix number	Gene description	Gene
105.94	0.006	1096_g_at	CD19 antigen	CD19
103.5	0.005	40103_at	villin 2	VIL2
80.41	0.009	2047_s_at	junction plakoglobin isoform 1	JUP
80.14	0.013	38017_at	CD79A antigen isoform 2 precursor	CD79A
77.12	0.025	39327_at	p53-responsive gene	PRG2
72.29	0.017	38269_at	protein kinase D2	PKD2
72.15	0.011	39318_at	T-cell lymphoma-1	TCL1A
66.16	0.022	854_at	B lymphoid tyrosine kinase	BLK
64.49	0.019	32238_at	bridging integrator 1	BIN1
61.79	0.028	38604_at	neuropeptide Y	NPY
57.28	0.049	41356_at	hypothetical protein FLJ10173	FLJ10173
56.67	0.028	41165_g_at	Immunoglobulin mu	IGHM
56.67	0.028	41165_g_at	B-cell CLL/lymphoma 11A zinc finger protein	BCL11A
55.58	0.038	32842_at	B-cell CLL/lymphoma 7A	BCL7A
52.05	0.025	493_at	casein kinase 1 delta	CSNK1D
49.7	0.03	36933_at	N-myc downstream regulated	NDRG1
48.04	0.025	38018_g_at	CD79A antigen isoform 2 precursor	CD79A
47.31	0.049	41151_at	SKIP for skeletal muscle and kidney enriched inositol phosphatase	SKIP

Table 46. Overall Success Rates of Class Predictors After Including the A, B, and C Cluster Distinctions

Description	Bayesian Net			SVM			Fuzzy Inference			Discriminant Analysis		
	r	C.I.	p-value	r	C.I.	p-value	r	C.I.	p-value	r	C.I.	p-value
ALL vs. AML	.912	[.76, .98]	<.001**	.971	[.85, 1.0]	<.001**	.971	[.85, 1.0]	<.001**	.853	[.69, .95]	<.001**
Remission. vs. Fail	.568	[.39, .73]	.256	.622	[.45, .78]	.094	.405	[.25, .58]	.906	.568	[.39, .73]	.256
Remission. vs. Fail in MLL	.471	[.23, .72]	.685	.647	[.38, .86]	.166	.471	[.23, .72]	.685	.353	[.14, .62]	.928
Remission. vs. Fail in Not MLL	.545	[.23, .83]	.500	.636	[.31, .89]	.274	.364	[.11, .69]	.886	.636	[.31, .89]	.274
Remission. vs. Fail in ALL	.542	[.33, .74]	.419	.625	[.41, .81]	.153	.375	[.19, .59]	.924	.500	[.29, .71]	.580
Remission. vs. Fail in AML	.461	[.19, .75]	.709	.769	[.46, .95]	.046*	.461	[.19, .75]	.709	.461	[.19, .75]	.709
Remission. vs. Fail in VX-GA	.714	[.29, .96]	.226	.714	[.29, .96]	.226	.857	[.42, .00]	.062	.714	[.29, .96]	.226
Remission. vs. Fail in VX-GB	.688	[.41, .89]	.105	.563	[.30, .80]	.401	.563	[.30, .80]	.401	.438	[.20, .70]	.772
Remission. vs. Fail in VX-GC	.714	[.42, .92]	.090	.714	[.42, .92]	.089	.500	[.23, .77]	.604	.500	[.23, .77]	.604
R/F Conditioned on VX-Groups	.703	[.53, .84]	.010**	.649	[.47, .80]	.049*	.595	[.42, .75]	.162	.514	[.34, .68]	.500

Table 46. Overall success rates of class predictors after including the A, B and C cluster predictions. r = Estimate of the success rate of the class predictor, C.I. = 95% confidence interval of the success rate of the class predictor, p -value = p -value of hypothesis test (see Supplemental Information).

* means that $r > 0.5$ at significance level $\alpha = 0.05$.

** means that $r > 0.5$ at significance level $\alpha = 0.01$.

Table 47. Discriminating genes that distinguish between remission and fail overall derived from SVM analysis.

	Affymetrix Locus number	Gene description	Gene symbol
1	41165_g_at 14q32.33	immunoglobulin heavy constant mu	IGHM
1	39389_at 12p13	CD9 antigen (p24)	CD9
2	41058_g_at 6p22.2	uncharacterized hypothalamus protein HT012	HT012
3	31459_i_at 22q11.1	immunoglobulin lambda locus	IGL
4	38389_at 12q24.1	2',5'-oligoadenylate synthetase 1 (40-46 kD)	OAS1
5	37504_at 7q21.1	E3 ubiquitin ligase SMURF1	SMURF1
6	40367_at 20p12	bone morphogenetic protein 2	BMP2
7	32637_r_at 16p12.3	PI-3-kinase-related kinase SMG-1	SMG1
8	39931_at 1q32	dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 3	DYRK3
9	37054_at 20q11	bactericidal/permeability-increasing protein	BPI
10	1404_r_at 17q11.2	small inducible cytokine A5 (RANTES)	SCYA5
11	1292_at 2q11	dual specificity phosphatase 2	DUSP2
12	37709_at Xp22.32	DNA segment, numerous copies	DXF68
13	36857_at 5p13.2	RAD1 (S. pombe) homolog	RAD1
14	41196_at 17q21	karyopherin (importin) beta 1	KPNB1

15	1182_at 2q33	phospholipase C, epsilon	PLCE
16	34961_at 3q13.13	T cell activation, increased late expression	TACTILE
17	37862_at 1p31	dihydrolipoamide branched chain transacylase (E2 component of branched chain keto acid dehydrogenase complex; maple syrup disease)	DBT
18	38772_at 1p31	cysteine-rich, angiogenic inducer, 61	CYR61
19	33208_at 13q32	DnaJ (Hsp40) homolog, subfamily C, member 3	DNAJC3
20	37837_at 18q23	KIAA0863 protein	KIAA0863
21	34031_i_at 7q21	cerebral cavernous malformations 1	CCM1
22	38220_at 1p22	dihydropyrimidine dehydrogenase	DPYD
23	34684_at 12p12	RecQ protein-like (DNA helicase Q1-like)	RECQL
24	39449_at 5p13	S-phase kinase-associated protein 2 (p45)	SKP2
25	32638_s_at 16p12.3	PI-3-kinase-related kinase SMG-1	SMG1
26	35957_at 16p13	stannin	SNN
27	34363_at 5q31	selenoprotein P, plasma, 1	SEPP1
28	35431_g_at 14q24.1	RNA polymerase II transcriptional regulation	MED6
29	35012_at 1q22	mediator (Med6, <i>S. cerevisiae</i> , homolog of) myeloid cell nuclear differentiation antigen	MNDA
30	38432_at 1p36.33	interferon-stimulated protein, 15 kDa	ISG15
31	35664_at 4q22	multimerin	MMRN
32	41862_at 11q25	KIAA0056 protein	KIAA0056

33	33210_at 14q	YY1 transcription factor	YY1
34	35794_at 8pter	KIAA0942 protein	KIAA0942
35	36108_at 6p21.3	HLA, class II, DQ beta 1	DQB1
36	35614_at 20q13.3	transcription factor-like 5 (basic helix-loop-helix)	TCFL5
37	32089_at 10p12	sperm associated antigen 6	SPAG6

Table 47. (Continuation). Discriminating genes that distinguish between remission and fail overall derived from SVM analysis.

	Affymetrix Locus number	Gene description	Gene symbol
38	1343_s_at 18q21.3	serine (or cysteine) proteinase inhibitor)	SERPINB
39	665_at 3p21.1	serine/threonine kinase 2	STK2
40	40901_at 14q13	nuclear autoantigen	GS2NA
41	39299_at 2q34	KIAA0971 protein	KIAA0971
42	34446_at 1q24	KIAA0471 gene product	KIAA0471
43	33956_at 8q13.3	MD-2 protein	MD-2
44	37184_at 7q11.23	syntaxin 1A (brain)	STX1A
45	1773_at 14q23	farnesyltransferase, CAAX box, beta	FNTB
46	34731_at 10q24.32	KIAA0185 protein	KIAA0185
47	41700_at 5q13	coagulation factor II (thrombin) receptor	F2R

48	38407_r_at	prostaglandin D2 synthase (21kD, brain) 9q34.2	GDS
49	40088_at	nuclear receptor interacting protein 1 21q11.2	NRIP1
50	33124_at	vaccinia related kinase 2 2p16	VRK2
51	32964_at	egf-like module containing, mucin-like, hormone 19p13.3	EMR1
		receptor-like sequence 1	
52	39560_at	chromobox homolog 6 22q13.1	CBX6
53	39838_at	CLIP-associating protein 1 2q14.2	CLASP1
54	40166_at	CS box-containing WD protein	LOC55884
55	36927_at	hypothetical protein, expressed in osteoblast 1p22.3	GS3686
56	41393_at	zinc finger protein 195 11p15.5	ZNF195
57	35041_at	neurotrophin 3 12p13	NTF3
58	40238_at	G protein-coupled receptor, family C, group 5, 16p12	GPRC5B
59	39926_at	MAD (mothers against decapentaplegic, Drosoph) 5q31	MADH5
60	36674_at	small inducible cytokine A4 17q21	SCYA4
61	32132_at	KIAA0675 gene product 3q13.13	KIAA0675
62	38252_s_at	1,6-glucosidase, 4-alpha-glucanotransferase 1p21	AGL
63	33598_r_at	cold autoinflammatory syndrome 1 1q44	CIAS1
64	37409_at	SFRS protein kinase 2 7q22	SRPK2
65	41019_at	phosducin-like 9q12	PDCL
66	1113_at	bone morphogenetic protein 2 20p12	BMP2

67	37208_at 7q11.2	phosphoserine phosphatase-like	PSPHL
68	32822_at 4q35	solute carrier family 25	SLC25A4
69	32249_at 1q32	H factor (complement)-like 1	HFL1
70	39600_at	EST	
71	32648_at 14q32	delta-like homolog (Drosophila)	DLK1
72	39269_at 13q12.3	replication factor C (activator 1) 3 (38kD)	RFC3
73	37724_at 8q24.12	v-myc avian myelocytomatosis viral oncogene	MYC
74	35606_at 15q21	histidine decarboxylase	HDC
75	31926_at 8q11	cytochrome P450, subfamily VIIA	CYP7A1
76	32142_at 8p22	serine/threonine kinase 3 (Ste20, yeast homolog)	STK3
77	32789_at 3q29	nuclear cap binding protein subunit 2, 20kD	NCBP2
78	37279_at 8q13	GTP-binding protein (skeletal muscle)	GEM
79	40246_at 3q29	discs, large (Drosophila) homolog 1	DLG1
80	37547_at 7p14	PTH-responsive osteosarcoma B1 protein	B1
81	32298_at 8p11.2	a disintegrin and metalloproteinase domain 2	ADAM2
82	40496_at 12p13	complement component 1, s subcomponent	C1S
83	39032_at 13q14	transforming growth factor beta-stimulated protein	TSC22

SUPPLEMENTARY INFORMATION

Sample management

- Cell suspensions from diagnostic bone marrow aspirates or peripheral
- 5 blood samples were handled according to the cryopreservation procedure of the St. Jude's Children's Hospital. Samples were retrieved from cryopreservation at -135°C and thawed quickly at 37°C and then washed by centrifugation at 1200 rpm for 5 minutes in warmed 20%(v/v) Fetal Bovine Serum in Dulbecco's Modified Minimum Essential Medium (Invitrogen, Grand Island, NY).
- 10 Cytospins were prepared from thawed samples, stained with Wright's stain and assessed for percent blasts and cell viability by light microscopy. Decanted cell pellets were used immediately for RNA purification.

RNA extraction and T7 amplification

- 15 An average of 2×10^7 cells were used for the total RNA extraction with the Qiagen RNeasy mini kit (VWR International AB, Stockholm, Sweden). The mean of the purified total RNA concentration was $0.5\mu\text{g}/\text{ul}$ (approximately $25\mu\text{g}$ of total RNA yield), as quantified with the RiboGreen assay (Molecular Probes, Eugene, OR). All samples met assay quality standards as recommended
- 20 by Affymetrix. The $\text{A}_{260\text{nm}}/\text{A}_{280\text{nm}}$ ratio was determined spectrophotometrically in 10 mM Tris, pH 8.0, 1mM EDTA, and all samples used for array analysis exceeded values of 1.8. The RNA integrity was analyzed by electrophoresis using the RNA 6000 Nano Assay run in the Lab-on-a Chip (Agilent Technologies, Palo Alto, CA). High quality RNA quality
- 25 criteria included a 28S rRNA / 18S rRNA peak area ratio >1.5 and the absence of DNA contamination. To prepare cRNA target, the mRNA was reverse transcribed into cDNA, followed by re-transcription in a method that uses two rounds of amplification devised for small starting RNA samples, kindly
- 30 provided by Ihor Lemischka (Princeton University), with the following modifications: linear acrylamide ($10\mu\text{g}/\text{ml}$, Ambion, Austin, TX) was used as a co-precipitant in steps that used alcohol precipitation and the starting amount of RNA was 2.5 ug of total RNA. Briefly, a T7- (dT) $_{24}$ oligonucleotide primer

(Genset Oligos, La Jolla, CA) was annealed to 2.5 ug of total RNA and reverse transcribed with Superscript II (Invitrogen, Grand Island, NY) at 42°C for 60 min. Second strand cDNA synthesis by DNA polymerase I (Invitrogen) at 16°C for 120 min was followed by extraction with phenol:chloroform:isoamyl
5 alcohol (25:24:1)(Sigma, St. Louis, MO) and microconcentration (Microcon 50. Millipore, Bedford, MA). RNA was then transcribed from the cDNA with a high yield T7 RNA polymerase kit (Megascript, Ambion, Austin, TX). The second round of amplification utilized random hexamer and T7- (dT) 24 oligonucleotide primers, Superscript II, DNA polymerase I and a biotin labeling
10 high yield T7 RNA polymerase kit (Enzo Diagnostics, Farmingdale, NY). The biotin-labeled cRNA was purified on RNeasy mini kit columns, eluted with 50ul of 45°C RNase-free water and quantified using the RiboGreen assay.

Target labeling and probe hybridization

15 Following quality check on Agilent Lab-on-a-Chip, 15 ug cRNA were fragmented for 35 minutes in 200mM Tris-acetate pH 8.1, 150mM MgOAc and 500 mM KOAc following the Affymetrix protocol (Affymetrix, Santa Clara, CA). The fragmented RNA was then hybridized for 20 hours at 45°C to HG_U95Av2 probes. The hybridized probe arrays were washed and stained
20 with the EukGE-WS2 fluidics protocol (Affymetrix), including streptavidin phycoerythrin conjugate (SAPE, Molecular Probes, Eugene, OR) and an antibody amplification step (Anti-streptavidin, biotinylated, Vector Labs, Burlingame, CA). HG_U95Av2 chips were scanned at 488 nm, as recommended by Affymetrix. The images were inspected to detect artifacts.
25 The expression value of each gene was calculated using Affymetrix GENECHIP software for the 12,625 Open Reading Frames on the probe set.

Data presentation and exclusion criteria

Criteria used as quality control for exclusion of poor sample arrays
30 included: total RNA integrity, cRNA quality, probe array image inspection, B2 oligo staining (used for Array grid alignment), and internal control genes (GAPDH value greater than 1800). Of the 142 cases initially selected, 126 were ultimately retained in the study; 16 cases were excluded from the final analysis

due to poor quality total RNA or cRNA amplification or a poor hybridization (low percentage of expressed genes <10%, poor 3'/5' amplification ratios).

Data Analysis

5

1. Data preprocessing

The preprocessing stage was divided in filtering and transformation. For filtering, the control probesets were removed (i.e. probesets whose accession ID starts with the AFFX prefix), as well as all probesets that had at least one
10 "absent" call (as determined by the Affymetrix MAS 5.0 statistical software) across all training set samples. In the transformation stage, the natural logarithm of the gene expression values (i.e. the signal values) was taken. This is the preprocessing method used for most of the analysis methods; except those in which different preprocessing is mentioned in the detailed information below.

15

2. Description of the supervised learning methods for class prediction

The exploratory evaluation of our data set was performed in several steps. The first step was the construction of predictive classification algorithms that linked gene expression data to patient outcome as well as the traditional clinical
20 variables that define prognosis. With previous knowledge of their sample nature, the 126 patients were divided into statistically balanced and representative training (82 patients) and test sets (44 patients), according to the clinical labels (leukemia lineage, cytogenetics and outcome). For classification purposes, several primary supervised approaches were used, including Bayesian
25 networks, recursive feature elimination in the context of Support Vector Machines (SVM-RFE), linear discriminant analysis and fuzzy logics.

Classification tasks were as follows:

- | | |
|---|---|
| - ALL vs. AML | - Remission. vs. Fail |
| - t(4;11) vs. not t(4;11) | - MLL vs. Not MLL |
| 30 - Remission. vs. Fail in ALL | - Remission. vs. Fail in AML |
| - Remission. vs. Fail in <i>VxInsight</i> cluster A cluster B | - Remission. vs. Fail in <i>VxInsight</i> |
| - Remission. vs. Fail in <i>VxInsight</i> cluster C | - MLL vs. Not MLL in ALL |

- MLL vs. Not MLL in AML
- Remission. vs. Fail in Not MLL

- Remission. vs. Fail in MLL

2.1. Bayesian Networks

5 We employed the Bayesian network framework described in (6), without
any data preprocessing. The Bayesian network modeling and learning paradigm
was introduced in Pearl (1988) and Heckerman *et al.* (1995), (7, 8) and has been
studied extensively in the statistical machine learning literature. Our work
tailors this paradigm to the analysis of gene expression data in general and to
10 the classification problem in particular. A Bayesian net is a graph-based model
for representing probabilistic relationships between random variables. The
random variables, which may, for example, represent gene expression levels,
are modeled as graph nodes; probabilistic relationships are captured by directed
edges between the nodes and conditional probability distributions associated
15 with the nodes. A Bayesian net asserts that each node is statistically
independent of all its no descendants, once the values of its parents (immediate
ancestors) in the graph are known. That is, a node n 's parents render n and its
no descendants *conditionally independent*. In our modeling, we consider
Bayesian nets in which each gene is a node, and the class label of interest is an
20 additional node C having no children. The conditional independence assertion
associated with (leaf) node C implies that the classification of a case q depends
only on the expression levels of the genes, which are C 's parents in the net.
More formally, distribution $Pr\{q[C] \mid q[genes]\}$ is identical to distribution
 $Pr\{q[C] \mid q[Par(C)]\}$, where $Par(C)$ denotes the parent set of C . Note, in
25 particular, that the classification does not depend on other aspects (other than
the parent set of C) of the graph structure of the Bayesian net. Thus, while the
Bayesian network model ultimately can be a highly appropriate tool for learning
global gene regulatory networks, in the context of classification tasks such as
those considered in this paper, the Bayesian network learning problem may be
30 reduced to the problem of learning subnetworks consisting only of the class
label and its parents. It is important to emphasize how this modeling differs
from that of a naïve Bayesian classifier (9, 10) and from the generalization
described in (11). A naïve Bayesian classifier assumes independence of the
attributes (genes), given the value of the class label. Under this assumption, the

conditional probability $Pr\{q[C] \mid q[genes]\}$ can be computed from the product $\prod_{g_i \in genes} Pr\{q[g_i] \mid q[C]\}$ of the marginal conditional probabilities. The naive Bayesian model is equivalent to a Bayesian net in which no edges exist between the genes, and in which an edge exists between every gene and the class labels. We make neither assumption. Rather, we ignore the issue of what edges may exist between the genes, and compute $Pr\{q[C] \mid q[genes]\}$ as $Pr\{q[C] \mid q[Par(C)]\}$, an equivalence that is valid regardless of what edges exist between the genes, provided only that $Par(C)$ is a set of genes sufficient to render the class label conditionally independent of the remaining genes.

Friedman *et al.* (1997) (11) drops the independence assumption of a naive Bayesian classifier and attempts to learn edges between the attributes (genes, in our context), while maintaining an edge from the class label into each attribute. This approach yields good improvements over naive Bayesian classifiers in the experiments (application domains other than gene expression data) reported in Friedman *et al.* (1997) (11). Our approach exploits a prior belief (supported by experimental results reported in (6) and in other gene expression analyses) that for the gene expression application domain, only a small number of genes is necessary to render the class label (practically) conditionally independent of the remaining genes. This both makes learning parent sets $Par(C)$ tractable, and generally allows the quantity $Pr\{q[C] \mid q[Par(C)]\}$ to be well estimated from a training sample. Even with the focus on restricted subnetworks, the learning problem is enormously difficult. Given a collection of training cases, we must learn one or more "plausible" Bayesian subnetworks, each consisting of class label node C and its parent set $Par(C)$. The main factors contributing to the difficulty of this learning problem are the large number genes, the fact that the expression values of the genes are continuous, and the fact that expression data generally is rather noisy. The approach to Bayesian network learning employed here identifies parent sets which are supported by current evidence by employing an external gene selection algorithm which produces between 20 and 30 genes using a measure of class separation quality similar to the *TNoM* score described in (12, 13). A binary binning of each selected gene's expression value about a point of maximal class separation also is performed. The set of selected genes then is searched exhaustively for parent sets of size 5 or less, with the

induced candidate networks being evaluated by the *BD* scoring metric (8). This metric, along with a variance factor, is used to blend the predictions made by the 500 best scoring networks (6). Each of these 500 Bayesian networks can be viewed as a competing hypothesis for explaining the current evidence (*i.e.*,
5 training data and simple priors) for the corresponding classification task, and the gene interactions each suggests are potentially of independent interest as well. Another significant aspect of our method involves a distinct normalization of the gene expression data for each classification task. We have found this a necessary follow-up step to the standard Affymetrix scaling algorithm. Our
10 approach to normalization is to consider, for each case, the average expression value over some designated set of genes, and to scale each case so that this average value is the same for all cases. This approach allows the analysis to concentrate on relative gene expression values within a case by standardizing a reference point between cases. The designated reference genes for a given
15 classification task are selected based on poorest class separation quality, which is a heuristic for identifying reference genes likely to be independent of the class label.

2.2 Support Vector Machines

20 Support vector machines (SVMs) are powerful tools for data classification (14, 15, 16). The development of the SVM was motivated, in the simple case of two linearly separable classes, by the desire to choose an optimal linear classifier out of an infinite number of linear classifiers that can separate the data. This optimal classifier corresponds not only to a hyperplane that
25 separates the classes but also to a hyperplane that attempts to be as far away as possible from all data points. If one imagines inserting the widest possible corridor between data points (with data points belonging to one class on one side of the corridor and data points belonging to the other class on the other side), then the optimal hyperplane would correspond to the imaginary
30 line/plane/hyperplane running through the middle of this corridor.

The SVM has a number of characteristics that make it particularly appealing within the context of gene selection and the classification of gene expression data, namely:

- The SVM is a multivariate classification algorithm that takes into account each gene simultaneously in a weighted fashion during training, and
- It scales quadratically with the number of training samples, N , and not with the number of features/genes, d .

5 In order to be computationally feasible, other methods first have to reduce the number of dimensions (features/genes), and then classify the data in the reduced space. A univariate feature selection process or filter ranks genes according to how well each gene individually classifies the data (13,17). The overall SVM classification is then heavily dependent upon how successful the

10 univariate feature selection process is in pruning genes that have little class-distinction information content. In contrast, the SVM provides an effective mechanism for both classification and feature selection via the Recursive Feature Elimination algorithm (18). This is a great advantage in gene

15 expression problems where d is much greater than N because the number of features does not have to be reduced a priori.

 Recursive Feature Elimination (RFE) is an SVM-based iterative procedure that generates a nested sequence of gene subsets whereby the subset obtained at iteration $k+1$ is contained in the subset obtained at iteration k . The genes that are kept per iteration correspond to genes that have the largest weight

20 magnitudes—the rationale being that genes with large weight magnitudes carry more information with respect to class discrimination than those genes with small weight magnitudes.

Implementation of RFE algorithm: The rate of reduction in the number of genes

25 via the RFE algorithm typically been geometric in nature (18,19). For example, in (18), 50% of the genes were removed per RFE iteration. However, as in (19), we have taken a less aggressive pruning approach with respect to the number of genes being removed per RFE iteration. In this work, the number of genes removed was constant within blocks of intervals: from 8000 to 1000 genes,

30 1000 genes were removed per iteration; from 900 to 200 genes, 100 genes were removed per iteration, etc.

 Leave-one-out cross-validation (LOOCV) was used to assess the performance of a linear SVM classifier. The LOOCV procedure divides the

training samples into N disjoint sets where the i^{th} set contains samples $1, \dots, i-1, i+1, \dots, N$. The SVM classifier is then trained on the i^{th} set and tested on the withheld i^{th} sample. This process is repeated for each set and the LOOCV error is the overall number of misclassifications divided by N . Note that the RFE

5 algorithm was performed separately on each leave-one-out fold—failure to do induces a selection bias that yields LOOCV error rates that are overly optimistic (20). If the benchmark for determining the number of genes to use in training the SVM classifier is based only upon RFE iterations with low LOOCV error, then one finds in practice many sets of gene numbers (e.g. 500, 100 or 50 genes)

10 that satisfy this criterion. Using only the training set LOOCV error, there is no obvious way to choose which number of genes should be used a priori on the test set. Indeed, classifiers using different numbers of genes will often lead to inconsistent predictions on the test set.

Instead of choosing one subset of genes out of many as the definitive gene

15 subset to be used on the test set, we instead use many subsets in a weighted voting scheme fashion. The gene subsets used corresponds to those sets with low LOOCV error. To determine the weight attributed to each subset of genes, metrics of classifier assessment other than LOOCV error were used. Once LOOCV has been performed, the SVM classifier is then retrained on the entire

20 training set.

Let $G = \{G_1, \dots, G_r\}$ denote the collection of gene subsets with low LOOCV error, where r is the number of gene subsets. The number of gene subsets, r , used in this study was determined by inspection. However, one can easily use LOOCV as a mechanism for determining r . Let $f_i(p_j)$ denote the prediction of

25 the i^{th} set, G_i , for the j^{th} patient, p_j , in the test set. The final prediction for the j^{th} patient, $f(p_j)$, consists of a linear combination of the predictions made by each set:

$$f(p_j) = \sum_{i=1}^r \alpha_i f_i(p_j)$$

where α_i is the weight attributed to each gene subset. In this work, α_i is

30 determined solely from the training set and consists of two components:

- A margin measure, $\text{median}_{i,k} g_i(p_k)y_k$, where $g_i(p_k)$ is the prediction made by the i^{th} set, G_i , for the k^{th} patient, p_k , in the training set; this margin measure, which is typically positive, is similar in spirit to the median margin metric used in (18).

- 5 - The median number of support vectors across r gene subsets.

The mathematical expression for α is a heuristic one: $\alpha_i = \alpha_{i1} + \alpha_{i2}$ where

$$\alpha_{i1} = \frac{m_i}{\sum_{i=1}^p m_i}, \text{ and } \alpha_{i2} = \frac{1/NSV_i}{\sum_{i=1}^p (1/NSV_i)},$$

such that m_i is the median margin measure, α_{i1} is the normalized margin measure, NSV_i is the median number of support vectors obtained using G_i as the feature set in the SVM classifier and α_{i2} is the normalized reciprocal of the number of support vector patients. The larger m_i is, the greater the influence G_i has on the overall vote since larger margins correspond to better separation between classes and presumably better separation in the test set. In contrast, the larger NSV_i is, the lesser the influence G_i has on the overall vote since separating hyperplanes determined by fewer support vectors tend to have better generalization.

The SVM and RFE algorithms were written in MATLAB (21). The particular SVM algorithm used was based upon the Lagrangian SVM formulation of Mangasarian and Musicant (22). The RFE approach with the voting scheme extension achieved the highest test set accuracy on the majority of the tasks examined in this work. The best test accuracy was achieved for the AML/ALL classification task while the performance on the other tasks were slightly better than the "majority-class" results—the results obtained if one were to always vote with the majority class. This is not surprising since the AML/ALL class distinctions tend to "dominate" the gene expression behavior. Since SVMs are not dependent upon an a priori and external feature/gene reduction procedure and can efficiently fold feature selection into the classification process, they will continue to perform well on tasks where the class distinctions dominate the gene expression behavior. Non-linear SVMs

were trained on several of the classification tasks, but their generalization performance on the test set, as expected, was far worse than the linear SVM classifiers. Since the patients already sparsely populate a very high-dimensional gene space, mapping to even higher-dimensional feature space via a nonlinear
5 kernel will only exacerbate the dilemma of over fitting, a condition already made worse due to the disturbingly small size of the training set relative to the number of genes and the large amount of experimental noise associated with microarray-generated data in general.

10 2.3 Class Prediction by Linear Discriminant Analysis

Discriminant analysis is a widely used statistical analysis tool (23). It can be applied to classification problems where a training set of samples, depending on some set of feature variables, is available. The idea is to find a linear or non-
15 linear function of the feature variables such that the value of the function differs significantly between different classes. The function is the so-called discriminant function. Once the discriminant function has been determined using the training set, we can predict the class that a new sample most likely belongs to.

20 Preprocessing: Not all of the original data were used in our analysis of the infant leukemia dataset. We eliminated all control genes (those with accession ID starting with the AFFX prefix) and those genes with all calls 'Absent' for all 142 samples. With these genes removed from the original 12625, we were left with 8414 genes. In addition, a natural log transformation was performed on
25 8414×142 matrix of the gene expression values prior to further analysis.

Selection of Significant Discriminating Genes for Binary Classifications: We assumed that the discriminating genes will be those with the most statistically significant difference between the two classes in a given binary classification
30 task. We evaluated each gene by checking if its expression value differed significantly between the two classes. This was done using the two-sample t -test. The larger the absolute value of the t -test statistic T , the greater the confidence that there is a difference between the expression values of the two

classes. The significance of the difference can be measured via the corresponding p -value, which provides a straightforward means of ranking the genes in order of importance.

5 *Class Prediction:* Once the genes have been ranked using the p -value, we need to select a subset as our discriminant variables. The expression values of these genes in the training set are used to determine a linear discriminant function, which discriminates between the two classes and also defines a trained classifier for making the class predictions for each sample in the test set. The question is
10 how to determine the optimal value for n . n must be less than the sample size of the training set, otherwise the covariance matrix of the samples in the training set will be singular and the discriminant function cannot be determined. Also, if n is too large the discriminant function may be over fitted to the data in the training set, which may lead to more misclassifications when it is used to make
15 predictions in test set. On the other hand, if n is too small, then the information contained in the feature set may be not sufficient for making accurate predictions. In practice, different prediction outcomes result when different numbers n of prediction genes are used in the classifier. To determine the class of a given sample from the test set, we have therefore we have chosen to use a
20 simple voting scheme. We make a series of predictions with the number n of prediction genes varying from 1/3 to 2/3 of the sample size of the training set. (For example, if the number of samples in the training set was 85, we computed predictions for the given sample from the test set using $n=28, 29, 30, \dots, 56$.) The dominant class predicted is then taken as the final prediction result for the
25 sample. Overall, the results of our discriminant analysis for classification tasks were not as good as those of the other multivariate methods (fuzzy logic, Bayesian, SVM) applied to these problems.

2.4 Fuzzy Interference Classification Methodology

30

Traditional classification methods are based on the theory of crisp sets, where an element is either a member of a particular set or not. However many objects encountered in the real world do not fall into precisely defined

membership criteria. Alternative forms of data classification, which allows for continuous membership gradations, have been investigated and introduced fuzzy logic theory (24).

In many applications, it is easier to produce a linguistic description of a system than a complex mathematical model. The advantage of fuzzy logic in these situations is its ability to describe systems linguistically through rule statements (25). Expert human knowledge can then be formulated in a systematic manner. For example, for a gene regulatory model, one rule statement might be: "If the activator A is high and the repressor B is low, then the target C would be high" (26).

A Fuzzy Inference System (FIS) contains four components: fuzzy rules, a fuzzifier, an inference engine, and a "defuzzifier" (27). The fuzzy rules, consisting of a collection of *IF-THEN* rules, define the behavior of the inference engine. The membership functions $\mu_F(x)$ provide measure of the degree of similarity of elements to the fuzzy subset.

In fuzzy classification, the training algorithm adapts the fuzzy rules and membership functions so that the behavior of the inference engine represents the sample data sets. The most widely used adaptive fuzzy approach is the neuro-fuzzy technique, in which learning algorithms developed for neural nets are modified so that they can also train a fuzzy logic system (28).

Preprocessing: The infant dataset we used consists of gene expression level for 12625 probesets on the Affymetrix U95Av2 chip, including 67 control genes, measured for 142 patients. The Affymetrix Microarray Suite (MAS) 5.0 assigns a "Present", "Marginal", or "Absent" call to the computed signal reported for each probeset [Affymetrix 2001]. Because of strong observed variations in the range of gene expression values across different experiments, it is necessary to preprocess the data prior to further analysis.

In the infant dataset, 17% of all the labels are "Present", 81% are "Marginal", and 2% are "Absent". We prefer not to eliminate too many probesets at the outset. So we choose a loose rule to filter the probesets. We assume that "reliable probesets" satisfy the following criteria:

1. They are not control genes;

2. For a given probeset, at least one label (across all patients) should be "Present".

Under these criteria, 8446 probesets survive.

For a given patient, the distribution of gene expression values is not uniform. It grows exponentially. After filtering, we therefore perform a base-10 logarithmic transformation of the gene expression data. This logarithmic transformation scales the data to assist in visualizations, remedies right-skewed distributions and makes error components additive (29). It also removes systematic variations in experiments. Previously, in our analysis of the MIT leukemia dataset (30), we have found that logarithmic transformation of the gene expression data improves fuzzy and neuro-fuzzy classification accuracies compared to untransformed data.

Feature Selection: Even after filtering, the dimension of our dataset, 8446, is still too large for a classification problem. It is well known that increasing the number of features beyond a value of the order of the number of samples can actually degrade classification performance rather than improving it (31). In addition, reducing the dimensionality of the feature space is necessary to decrease the cost and time of classification (32). Here we use rank ordering statistics for feature selection.

Our method is as follows. For a given classification task, we rank the genes according to the average signal intensity across the patients in each class. We then calculate the difference in rank position between the two classes for each gene and order these genes with increasing value of the rank difference. The larger the absolute difference in rank for a gene, the more important that gene is. Rank ordering identifies the genes with the most "discriminating power" for distinguishing the two classes. Finally, we select the top 100 genes, corresponding to the 100 largest rank ordering differences, as our discriminating genes, for input to the fuzzy classifier.

Classification Approach: The 100 "top" genes determined in the feature selection step are in reality an upper bound for the optimal number, k^* , of discriminating genes. We note, too, that k^* will vary according to classification

task because the training model will be different for each task. Here, we have used Leave One Out Cross Validation (LOOCV) to determine k^* for each task (33).

5 We followed standard LOOCV methodology to compute the prediction
error of our classification method. This procedure iterated k from 1 to
100 in the dataset, where k is the number of top discriminating genes
training our model. Within each iteration, we iteratively removed a
single patient from the data set and trained the classification procedure
10 using k discriminating genes on the rest of the patients. We then applied
the trained classifier to the held-out patient and compared the predicted
class to the true class. The number of prediction errors is f^k and the
LOOCV error is e^k . The optimal solution, k^* , corresponds to
$$\min_k (e^k \times f^k).$$

With the number of genes now fixed at k^* , we used the labeled training dataset
15 to generated a Sugeno-type fuzzy inference system using the Fuzzy Logic
Toolbox in Matlab (34). This uses the fuzzy c-means technique to partition each
data point to a degree specified by a membership grade, and subtractive
clustering to initialize the iterative optimization. For comparison, we also
implemented an adaptive neuro-fuzzy inference system (ANFIS) to tune the
20 parameters of the fuzzy membership functions based on knowledge learned
from the modeling data. Training an ANFIS is an optimization task with the
goal of finding a set of weights that minimizes an error measure. In our tests, we
found that this procedure increased the computational burden significantly, but
provided only marginal performance improvement. Once the classifier was
25 trained, we can use it to predict the class type of the test dataset. For a given
new patient, the inputs to the FIS are signal intensities of the top k^* genes. The
output of the FIS is the classification result for this patient. The ideal output for
the ALL class is 1 and the ideal output for the AML class is -1. The larger the
distance between the actual prediction and 1/-1 is, the less strong the prediction.
30 Fuzzy methods share a number of features in common with neural networks and
with probabilistic methods (such as Bayesian approaches), however they have
several unique advantages, which suggest interesting avenues for future
research. In particular, their ability to naturally incorporate non-numeric data

expert into a model, opens the possibility of the use of expert data priors such as clinical assessments within the classification system. Similarly, incomplete knowledge about gene interrelationships may be incorporated into gene-expression-based models of regulatory networks.

5

3. Methods for evaluating the performance of class predictors

Four class predictors—based on the techniques of Bayesian Networks, Support Vector Machines (SVM), Fuzzy Inference and Discriminant Analysis, as
10 described in the previous section—have been applied to thirteen supervised binary classification tasks using gene expression microarray data for the cohort of infant leukemia patients studied in the present work. In this section we describe the statistical methods we have used for evaluating the performance of the four class predictors based on their prediction results with respect to the
15 thirteen tasks.

In any binary classification task, there are four possible prediction outcomes characterized as *true-positive (TP)*, *false-positive (FP)*, *true-negative (TN)* and *false-negative (FN)*. In the former two instances, a sample is, respectively,
20 correctly or incorrectly classified into Class A, while the latter two instances correspond to classification into Not-Class A. Consequently, the performance of a class predictor can always be completely summarized in terms of a 2×2 matrix as shown in Table 48.

25

Table 48. Prediction Outcome Probabilities of a Class Predictor

Original Classes	Predicted Classes		Row Sum
	Class A	Not-Class A	
Class A	$TP = \text{true-positive probability}$	$FN = \text{false-negative probability}$	1
Not-Class A	$FP = \text{false-positive probability}$	$TN = \text{true-negative probability}$	1

Note that because each row sums to 1 only one quantity is required from each row in order to determine the entire matrix. In other words, there are only two independent quantities in Table 48. These can be regarded as evaluating the different aspects of the class predictor's performance. Improving a class predictor's performance in TP may lower its TN , while its TN may be improved at the cost of reducing of its TP . In order to evaluate the *overall* performance of a class predictor, therefore, a measure that combines the two independent quantities is needed.

We considered two such overall measures: the success rate r , and the odds ratio OR . The success rate is defined as the probability of correct prediction. This is just a weighted average of TP and TN :

$$r = w_1 TP + w_2 TN, \quad [1]$$

where w_1 = actual proportion of Class A in the test set, and $w_2 = 1 - w_1$. TP and TN are intrinsic values associated with a given predictor, and are unknown; therefore r is also unknown and must be estimated. A commonly used point estimate of r , which we have utilized here, is the ratio of the number of correct predictions to the total number of predictions. We have also computed the 95% confidence intervals of r (35). Finally, we have performed a significance test to evaluate the extent to which the performance of a predictor differs from what would have been obtained by chance alone. This is equivalent to testing the statistical hypotheses

$$H_0: r = 0.5 \text{ verses } H_A: r > 0.5. \quad [2]$$

If the p -value (35) of the test is no larger than a given significance level α (here, we have set $\alpha = 0.05$ and $\alpha = 0.01$), then we reject the null hypothesis H_0 and

conclude that the difference is significant at level α . The p -value is closely related to the success rate: the larger the success rate, the smaller the expected p -value. Thus, either success rate or the p -value can be used to measure the performance of a predictor. For each of four class predictors, and with respect to
5 each of thirteen tasks, we have computed the point estimate and confidence interval of r . These are presented in Table 48, along with the p -value corresponding to the statistical test of hypotheses [2].

The second overall measure that we utilized is the odds ratio (OR). Since a good
10 class predictor should simultaneously satisfy

$$TP > FN \text{ and } FP < TN, \quad [3]$$

or equivalently,

$$TP / FN > 1 \text{ and } FP / TN < 1, \quad [4]$$

this implies that the ratio of the right hand sides of the inequalities in [4], i.e.,

$$15 \quad OR = \frac{TP / FN}{FP / TN}, \quad [5]$$

should be large (at least larger than 1). Hence this ratio—known as the odds ratio (29)—can be utilized as an overall measure for evaluating the class predictor's performance. For each of the four class predictors and each of the thirteen tasks, the estimated value of OR and its 95% exact confidence interval
20 (36) have been calculated through the use of SAS package (37), and the results are listed in Table 49.

Above, we observed that the expected values for the TP and FP of a good class predictor should satisfy $TP > FP$ or $TP/FP > 1$, which is mathematically
25 equivalent to $OR > 1$. This suggests that the performance of a classifier can alternatively be evaluated by testing the following hypotheses:

$$H_0: TP \leq FP \text{ vs. } H_A: TP > FP, \quad [6]$$

or equivalently

$$H_0: OR \leq 1 \text{ vs. } H_A: OR > 1. \quad [7]$$

30 Hence the p -value of the test also serves as a good measure for evaluating the performance of the class predictor. An *uniformly most powerful unbiased test*—

known as Fisher's exact test (38)—has been used to test the hypotheses [7] and the p -values of the test are given in Table 49.

From Tables 48 and 49 it is evident that all of the four class predictors
5 performed well on Tasks 1 and 3. The statistical test for hypotheses [2] rejects
the null hypothesis H_0 and we may conclude that the predictions made by the
four class predictors on these tasks are significantly better than those made by
chance, at level $\alpha = 0.01$. Fisher's exact test yields the similar results, except
that for two of the predictors (fuzzy inference and discriminant analysis), the
10 significance level for Task 3 predictions is $\alpha = 0.05$.

Table 49. Overall Success Rates of Class Predictors

Task #	Description	Bayesian Net			SVM			Fuzzy Inference			Discriminant Analysis		
		r	C.I.	p-value	r	C.I.	p-value	r	C.I.	p-value	r	C.I.	p-value
1	ALL vs. AML	.886	[.73, .97]	.000**	.943	[.81, .99]	.000**	.943	[.81, .99]	.000**	.829	[.66, .93]	.000**
2	Remission. vs. Fail	.514	[.34, .69]	.500	.629	[.45, .79]	.087	.514	[.34, .69]	.500	.514	[.34, .69]	.500
3	t(4;11) vs. Not t(4;11)	.818	[.65, .93]	.000**	.879	[.72, .97]	.000**	.788	[.61, .91]	.000**	.788	[.61, .91]	.000**
4	MLL vs. Not MLL	.643	[.44, .81]	.092	.607	[.41, .78]	.172	.679	[.48, .84]	.043*	.679	[.48, .84]	.043*
5	Remission. vs. Fail in ALL	.542	[.33, .74]	.419	.625	[.41, .81]	.153	.375	[.19, .59]	.924	.500	[.29, .71]	.580
6	Remission. vs. Fail in AML	.429	[.18, .71]	.788	.714	[.42, .92]	.089	.429	[.18, .71]	.788	.500	[.23, .77]	.604
7	Remission. vs. Fail in VX-GA	.714	[.29, .96]	.226	.714	[.29, .96]	.226	.857	[.42, .00]	.062	.714	[.29, .96]	.226
8	Remission. vs. Fail in VX-GB	.625	[.35, .85]	.227	.563	[.30, .80]	.401	.563	[.30, .80]	.401	.438	[.20, .70]	.772
9	Remission. vs. Fail in VX-GC	.786	[.49, .95]	.028*	.714	[.42, .92]	.089	.500	[.23, .77]	.604	.500	[.23, .77]	.604
10	MLL vs. Not MLL in ALL	.650	[.41, .85]	.131	.600	[.36, .81]	.251	.700	[.46, .88]	.057	.550	[.32, .77]	.411
11	MLL vs. Not MLL in AML	.750	[.35, .97]	.144	.375	[.09, .76]	.855	.625	[.24, .91]	.363	.500	[.16, .84]	.636
12	Remission. vs. Fail in MLL	.471	[.23, .72]	.685	.647	[.38, .86]	.166	.471	[.23, .72]	.685	.353	[.14, .62]	.928
13	Remission. vs. Fail in Not MLL	.545	[.23, .83]	.500	.636	[.31, .89]	.274	.364	[.11, .69]	.886	.636	[.31, .89]	.274

KEY: r = Estimate of the success rate of the class predictor.

C.I. = 95% confidence interval of the success rate of the class predictor.

p-value = p-value of hypothesis test [2] (see text).

* means that $r > 0.5$ at significance level $\alpha = 0.05$.

** means that $r > 0.5$ at significance level $\alpha = 0.01$.

Table 50. Estimates of Odds Ratios and Fisher's Exact Test

Task #	Bayesian Net			SVM			Fuzzy Inference			Discriminant Analysis		
	OR	C. I.	p-value	OR	C. I.	p-value	OR	C. I.	p-value	OR	C. I.	p-value
1	76.0	[5.950, 3408]	0.000**	252.00	[11.3, 11216]	0.000**	∞	[12.84, ∞]	0.000**	21.11	[2.84, 180]	0.000**
2	0.80	[.134, 4.27]	0.746	2.40	[.324, 19.3]	0.270	0.68	[.091, 4.15]	0.806	1.00	[.204, 4.78]	0.635
3	∞	[1.867, ∞]	0.005**	∞	[4.324, ∞]	0.000**	14.67	[1.06, 754]	0.021*	∞	[1.064, ∞]	0.022*
4	2.88	[.459, 18.5]	0.175	2.50	[.414, 16.2]	0.220	4.89	[.739, 37.7]	0.060	3.89	[.521, 32.1]	0.123
5	0.79	[.057, 7.45]	0.762	1.86	[.109, 30.2]	0.486	0.14	[.003, 1.678]	0.991	0.91	[.126, 6.39]	0.700
6	0.00	[0.0, 7.081]	1.000	∞	[.264, ∞]	0.165	0.00	[0.00, 7.08]	1.000	1.00	[.077, 13.0]	0.704
7	∞	[.142, ∞]	0.286	4.00	[.026, 391]	0.524	∞	[.283, ∞]	0.143	∞	[.142, ∞]	0.286
8	----	----	1.000	0.00	[0.00, 65]	1.000	0.00	[0.00, 65]	1.000	0.30	[.005, 4.884]	0.942
9	∞	[.653, ∞]	0.055	∞	[.264, ∞]	0.165	0.60	[.009, 15.5]	0.846	0.60	[.009, 15.5]	0.846
10	3.00	[.240, 44.7]	0.296	4.57	[.316, 253]	0.221	8.00	[.526, 432]	0.098	1.00	[.065, 11.8]	0.693
11	5.00	[.032, 469.3]	0.464	∞	[0.009, ∞]	0.750	0.00	[0.00, 117]	1.000	∞	[.053, ∞]	0.536
12	0.00	[0.00, 4.429]	1.000	2.25	[.116, 40.2]	0.445	0.60	[.040, 6.80]	0.840	0.29	[.019, 3.355]	0.957
13	0.83	[.011, 24.1]	0.788	1.50	[.017, 46.9]	0.661	0.00	[0.00, 4.16]	1.000	1.50	[.017, 46.9]	0.661

KEY: OR = Estimate of the odds ratio.

C.I. = 95% confidence interval of the odds ratio.

p-value = p-value of Fisher's exact test.

* means that OR > 1 at significance level $\alpha = 0.05$.

** means that OR > 1 at significance level $\alpha = 0.01$.

4. Unsupervised methods - Clustering methodology

Three types of methodologies were used in the clustering analysis, namely agglomerative hierarchical clustering, Principal Component Analysis and a force-directed clustering algorithm coupled with the *VxInsight*

5 visualization tool.

4.1 Agglomerative Hierarchical clustering

The grouping together, or clustering, of genes with similar patterns of expression is based on the mathematical measure of their similarity, e.g. the
10 Euclidian distance, angle or dot products of the two n -dimensional vectors of a series of n measurements. Biological interpretation of DNA microarray hybridization gene expression data has utilized clustering to re-order genes, and conversely samples into groups which reflect inherent biological similarity. Clustering methods can be divided into two classes, supervised and
15 unsupervised. In supervised clustering vectors are classified with respect to known reference vectors. Unsupervised clustering uses no defined vectors. With a diverse dataset of 126 infant leukemia patients and our intent to discover unique patterns within, we chose to use an unsupervised clustering approach. In addition, combining the ordered list of genes and patients with a graphical
20 presentation of each data point using relative value-color, termed a "heat map", aids the viewer in an intuitive manner. Several computer software programs allow one to cluster significant samples and genes and create graphical output (Cluster, Genespring, GeneCluster).

We have applied the Eisen (39) Cluster algorithm utilizing pair wise
25 average-linkage cluster analysis to gene expression data from Affymetrix U95Av2 arrays. Genes were selected for this analysis if the Affymetrix Microarray Analysis Software v. 5.0 predicted at least 1 of 126 patient data were "Present". The resulting 8,358 genes were z-scored across patients and the standard deviation determined. The clustering algorithm of genes is as follows:
30 the distance between two genes is defined as $1-r$ where r is the correlation coefficient between the 252 values of the two genes across samples. Two genes with the closest distance are first merged into a super-gene and connected by branches with length representing their distance, and are deleted from future

merging. The expression level of the newly formed super-gene is the average of standardized expression levels of the two genes (average-linked) across samples. Then the next super-gene with the smallest distance is chosen to merge and the process repeated 8,352 times to merge all 8,353 genes.

5

4.2 Principal Component Analysis

Principal component analysis (PCA) is a well-known and convenient method for performing unsupervised clustering of high-dimensional data.

Closely related to the Singular Value Decomposition (SVD), PCA is an
10 unsupervised data analysis technique whereby the most variance is captured in the least number of coordinates (40-42). It can serve to reduce the dimensionality of the data while also providing significant noise reduction. PCA can also be applied to gene-expression data obtained from microarray experiments. When gene expressions are available from a large number of
15 genes and from numerous samples, then the noise suppression and dimension reduction properties of PCA can greatly facilitate and simplify the examination and interpretation of the data. In any microarray experiment, the expression profiles of many genes are monitored simultaneously. Because many genes are often up or down regulated in similar patterns in the cells, these responses are
20 correlated. PCA can identify the uncorrelated or independent sources of variation in the gene expression data from multiple samples. Since random noise tends to be uncorrelated with the signal, PCA does an effective job at separating the signal from the noise in the data.

If the gene expression values from each microarray are written as row
25 vectors, then the entire data set from multiple microarray samples can be represented by a data matrix whose rows represent the gene expressions from each microarray chip. PCA can greatly reduce the complexity and dimensionality of the data by factor analyzing the data matrix into the product of two much smaller matrices. The two smaller matrices are known as scores
30 and loading vectors (or eigenvectors). The decomposition is often achieved with a method known as singular value decomposition (SVD). PCA has the unique property that the decomposition is performed such that the rows of the score matrix are orthogonal and the columns of the eigenvector matrix are also

orthogonal. Although there is a strict mathematical definition of orthogonal, orthogonal vectors are simply independent and uncorrelated with one another. Therefore, these vectors represent unique sources of variation in the microarray data. Another property of the eigenvectors is that they are calculated such that
5 the first eigenvector represents the largest source of variance in the data, the second represents the next largest unique source of variance in the data, and so on. Since we generally expect the signal in the data to be larger than the noise and since random noise is approximately orthogonal to the signal, PCA has the ability to separate the noise from signal that we are interested in. By ignoring
10 the eigenvectors with low variance, we can observe the portion of the data that contains primarily signal.

The scores matrix represents the amounts of each eigenvector in each sample that are required to reproduce the data matrix. When we eliminate the noisier eigenvectors we also eliminate their associated scores. The scores
15 represent a compressed form of the data matrix in the new coordinate system of the eigenvectors. Since scores are derived from the expression of many genes and many samples, they have much higher signal-to-noise ratios than the individual gene expressions upon which they are based. A plot of the scores for each microarray for each eigenvector then is a new compressed form of the
20 gene expression data for all samples. 2D plots of one set of scores vs. another for two selected eigenvectors allow us an examination of the microarray data in the compressed PCA space so that we can readily observe clusters in expression data. 3D plots are also possible when the scores from three selected eigenvectors are displayed. Statistical metrics can be used to identify groupings
25 or clusters in the data in 2, 3, or higher dimensions that cannot be readily viewed graphically. All the statistical supervised and unsupervised clustering methods that are based on individual genes or groups of genes can be applied to the scores representation of the data.

The first three Principal Components partition the infant cohort into two
30 different groups. Interestingly, these groups display a weak correlation with the infant ALL/AML lineage membership (and none with the MLL cytogenetics), although the correlation is not seen until the second PC. This indicates, according to the theory behind PCA, that the ALL/AML distinction is not the

driving force behind the representation of the patient cohort. The first (and most important) Principal Component, on the other hand, does not reveal any obvious clusters. Upon further analysis, however, we did find an additional interesting group correlated with the first Principal Component. This group was
5 discovered by a force-directed graph layout algorithm and the *VxInsight*® visualization program (43, 44).

4.3 *VxInsight* and the force directed clustering algorithm

This clustering algorithm places genes into clusters such that the sum of two
10 opposing forces is minimized. One of these forces is repulsive and pushes pairs of genes away from each other as a function of the density of genes in the local area. The other force pulls pairs of similar genes together based on their degree of similarity. The clustering algorithm stops when these forces are in equilibrium. Every gene has some correlation with every other gene; however,
15 most of these are not strong correlations and may only reflect random fluctuations. By using only the top few genes most similar to a particular gene as it is placed into a cluster we obtain two benefits. First, the algorithm runs much faster. Second, as the number of similar genes is reduced, the average influence of the other, mostly uncorrelated genes diminishes. This change
20 allows the formation of clusters even when the signals are quite weak. However, when too few genes are used in the process, the clusters break up into tiny random islands, so selecting this parameter is an iterative process. One trades off confidence in the reliability of the cluster against refinement into sub-clusters that may suggest biologically important hypotheses. These clusters are
25 only interpreted as suggestions, and require further laboratory and literature work before we assign them any biological importance. However, without accepting this trade off, it may be impossible to uncover any suggestive structure in the collected data. For example, we clustered using the twenty other genes most strongly similar to each gene. When we re-cluster using only the top
30 ten most strongly similar genes, the observed clusters have broken up into smaller groups. We carefully analyzed these for biological support and believe that they may be suggestive of weak, but important groupings in our experimental data. *VxInsight* was employed to identify clusters of patients with

similar gene expression patterns, and then to identify which genes strongly contributed to the separations. That process created lists of genes, which when combined with public databases and research experience, suggest possible biological significances for those clusters. The array expression data were clustered by rows (similar genes clustered together), and by columns (patients with similar gene expression clustered together). In both cases Pearson's R was used to estimate the similarities. These similarities were used together with a force-directed, two-dimensional clustering algorithm (43, 44) to produce maps showing clusters of genes and patients. Different maps were generated by using the top twenty, top ten and top five strongest correlations for each gene (using more similarity links between genes generates more stable clusters, while using fewer links leads to finer, if less stable, divisions). This methodology has been useful in inferring functions of uncharacterized genes clustered near other genes with known functions (45, 46), and did contribute to our analysis here, too. However, patients were the main focus of this study and most of the analysis revolved around the map of patient clusters. Analysis of variance (ANOVA) was used to determine which genes had the strongest differences between pairs of patient clusters. These gene lists were sorted into decreasing order based on the resulting F-scores, and were presented in an HTML format with links to the associated OMIM pages, which were manually examined to hypothesize biological differences between the clusters.

We also investigated the stability of those gene lists using statistical bootstraps (47, 48). For each pair of clusters we computed 1000 random bootstrap cases (resampling with replacement from the observed expressions) and computed the resulting ordered lists of genes using the same ANOVA method as before. The average order in the set of bootstrapped gene lists was computed for all genes, and reported as an indication of rank order stability (the percentile from the bootstraps estimates a p-value for observing a gene at or above the list order observed using the original experimental values). Because the force directed placement algorithm used by VxInsight has a stochastic element (random initial starting conditions), we used massively parallel computers to calculate hundreds of reclustering with different seeds for the random number generator. We compared pairs of ordinations by counting,

for every gene, the number of common neighbors found in each ordination. Typically, we looked in a region containing the 20 nearest neighbors around each gene, in which case one could find (around each gene) a minimum of 0 common neighbors in the two ordinations, or a maximum of 20 common

5 neighbors. By summing across every one of the genes an overall comparison of similarity of the two ordinations can be computed. We computed all pair wise comparisons between the randomly restarted ordinations and found the ordination that had the largest count of similar neighbors across the totality of all the comparisons. Note that this corresponds to finding the ordination whose

10 comparison with all the others has minimal entropy, and in a general sense represents the most central ordination (MCO) of the entire set. It is possible to use these comparison counts (or entropies) as similarity measures to compute another round of ordinations. The clusters from this recursive use of the ordination algorithm are generally smaller, much tighter, and are generally more

15 stable with respect to random starting conditions than any single ordination. We used all of these methods during exploratory data analysis to develop intuition about the data.

5. Lists of Informative Genes

20 Table 51. Discriminating genes that distinguish between ALL and AML types, derived from Bayesian networks analysis.

A. Bayesian Networks			
	Affymetrix Locus number	Gene description	Gene symbol
30	1	38269_at 19q13.2	protein kinase D2 PKD2
	2	40103_at 6q25-q26	villin 2 (ezrin) VIL2
35	3	41165_g_at 14q32.33	immunoglobulin heavy constant mu IGHM
	4	40310_at 4q32	toll-like receptor 2 TLR2
	5	38604_at 7p15.1	neuropeptide Y NPY
40	6	39689_at 20p11.2	cystatin C CST3
	7	41356_at 2p15	B-cell CLL/lymphoma 11A BCL11A

	8	461_at	N-acylsphingosine amidohydrolase	ASAH
		8p22-p21.3		
	9	1096_g_at	CD19 antigen	CD19
		16p11.2		
5	10	36938_at	N-acylsphingosine amidohydrolase	ASAH
		8p22-p21.3		
	11	41401_at	cysteine and glycine-rich protein 2	CSRP2
		12q21.1		
10	12	41523_at	RAB32, member RAS oncogene family	RAB32
		6q24.2		
	13	40432_at	Homo sapiens, clone IMAGE:4391536	
	14	41164_at	immunoglobulin heavy constant mu	IGHM
		14q32.33		
15	15	36766_at	ribonuclease, RNase A family, 2	RNASE2
		14q24-q31		
	16	39827_at	hypothetical protein	FLJ20500
		10pterq26		
	17	37001_at	calpain 2, (m/II) large subunit	CAPN2
		1q41-q42		
20	18	279_at	nuclear receptor subfamily 4	NR4A1
		12q13		
	19	39593_at	Similar to fibrinogen-like 2, clone	
	20	41038_at	neutrophil cytosolic factor 2	NCF2
		1q25		
25	21	40936_at	cysteine-rich motor neuron 1	CRIM1
		2p21		
	22	32227_at	proteoglycan 1, secretory granule	PRG1
		10q22.1		
30	23	478_g_at	interferon regulatory factor 5	IRF5
		7q32		
	24	1230_g_at	cisplatin resistance associated	CRA
		1q12-q21		
	25	35367_at	lectin, galactoside-binding, soluble	LGALS3
		14q21-q22		
35				

Table 52. Discriminating genes that distinguish between ALL and AML types, derived from SVM analysis.

40	B. SVM			
		Affymetrix	Gene description	Gene
45		Locus		symbol
		number		
	1	41165_g_at	immunoglobulin heavy constant mu	IGHM
		14q32.33		
	2	36766_at	ribonuclease, RNase A family, 2	RNASE2
50		14q24		
	3	38604_at	neuropeptide Y	NPY
		7p15.1		
	4	36879_at	endothelial cell growth factor 1	ECGF1
		22q13.33		
55			(platelet-derived)	
	5	41401_at	cysteine and glycine-rich protein 2	CSRP2
		12q21.1		
	6	36638_at	connective tissue growth factor	CTGF
		6q23.1		

7	33856_at Xq26	CAAX box 1	CXX1
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Table 52. (Continuation) Discriminating genes (between ALL and AML types) derived from SVM analysis.

		Affymetrix Locus number	Gene description	Gene symbol
10	8	35926_s_at 19q13.4	leukocyte immunoglobulin-like receptor, B	LILRB1
15	9	40659_at 9q22	nuclear receptor subfamily 4, group A, member 3	NR4A3
	10	266_s_at 6q21	CD24 antigen (small cell lung carcinoma cluster 4)	CD24
20	11	34180_at 8p23	Rho guanine nucleotide exchange factor (GEF) 10	ARHGEF
	12	279_at 12q13	nuclear receptor subfamily 4, group A, member 1	NR4A1
	13	38661_at 20q13.31	seb4D	HSRNA
25	14	38363_at 19q13.1	TYRO protein tyrosine kinase binding protein	TYROBP
	15	36657_at 19q13.2	apolipoprotein C-II	APOC2
30	16	37050_r_at	translocase of outer mitochondrial membrane 34	TOM34
	17	41523_at 6q24.2	RAB32, member RAS oncogene family	RAB32
	18	39878_at 13q14.3	protocadherin 9	PCDH9
35	19	41577_at 20q11.23	protein phosphatase 1, regulatory (inhibitor)	PPP1R1
	20	854_at 8p23-p22	B lymphoid tyrosine kinase	BLK
	21	38403_at Xq24	lysosomal-associated membrane protein 2	LAMP2
40	22	39994_at 3p21	chemokine (C-C motif) receptor 1	CCR1
	23	33186_i_at	ESTs	
	24	32227_at 10q22.1	proteoglycan 1, secretory granule	PRG1
45	25	39827_at 10pterq26	hypothetical protein	FLJ20500
	26	40103_at 6q25-q26	villin 2 (ezrin)	VIL2
50	27	34168_at 10q23	deoxynucleotidyltransferase, terminal	DNTT
	28	36465_at 7q32	interferon regulatory factor 5	IRF5
	29	34433_at 2p13	docking protein 1	DOK1
55	30	41239_r_at 1q21	cathepsin S	CTSS
	31	40457_at 11	splicing factor, arginine/serine-rich 3	SFRS3

	32	32827_at 11pter-	related RAS viral (r-ras) oncogene homolog 2	RRAS2
		p15.5		
5	33	33678_i_at	tubulin, beta, 2	TUBB2
	34	40936_at 2p21	cysteine-rich motor neuron 1	CRIM1
	35	38242_at 10q23.2-	B-cell linker	BLNK
10		q23.33		
	36	41164_at 14q32.33	immunoglobulin heavy constant mu	IGHM
	37	40220_at	HMBA-inducible	HIS1
15		17q21.32		
	38	40310_at 4q32	toll-like receptor 2	TLR2
	39	39593_at	Similar to fibrinogen-like 2, IMAGE:4616866	
	40	37844_at	class I cytokine receptor	WSX-1
20		19p13.11		
	41	478_g_at 7q32	interferon regulatory factor 5	IRF5
	42	38138_at 1q21	S100 calcium-binding protein A11 (calgizzarin)	S100A11
25	43	40282_s_at 19p13.3	D component of complement (adipsin)	DF
	44	36928_at 19q13.1	zinc finger protein 146	ZNF146
	45	34800_at	ortholog of mouse integral membrane glycoprotein	LIG1
30	46	33462_at 3q21-q25	G protein-coupled receptor 105	GPR105
	47	34950_at 16q12	OLF-1/EBF associated zinc finger gene	OAZ
	48	34335_at 13q33	ephrin-B2	EFNB2
35		13q33		
	49	37190_at 6q21-q22	WAS protein family, member 1	WASF1
	50	40195_at 11q23.2-	H2A histone family, member X	H2AFX
40		q23.3		
	51	38037_at 5q23	diphtheria toxin receptor	DTR
45	52	38994_at 12q	STAT induced STAT inhibitor-2	STATI2

Table 52. (Continuation). Discriminating genes (between ALL and AML types) derived from SVM analysis.

50		Affymetrix Locus number	Gene description	Gene symbol
55	53 6p21.3	38096_f_at	MHC class II, DP beta 1	HLA-DPB
	54	2063_at 13q22	excision repair cross-complementing rodent repair deficiency, complementation group 5 (xeroderma	ERCC5

	55	461_at 8p22-	pigmentosum, complementation group G) N-acylsphingosine amidohydrolase	ASAH
5		p21.3		
	56	35449_at 12p13	killer cell lectin-like receptor subfamily B - 1	KLRB1
	57	41198_at 17q21.32	granulin	GRN
10	58	38993_r_at	Homo sapiens cDNA: clone HEP03585	
	59	34677_f_at	Homo sapiens mRNA for TL132	
	60	33899_at 1q22-q23	aldehyde dehydrogenase 9 family, member A1	ALDH9A1
	61	40814_at	iduronate 2-sulfatase (Hunter syndrome)	IDS
15		Xq28		
	62	33228_g_at 21q22.11	interleukin 10 receptor, beta	IL10RB
	63	33458_r_at 6p21.3	H2B histone family, member L	H2BFL
20	64	41356_at 2p15	B-cell CLL/lymphoma 11A (zinc finger protein)	BCL11A
	65	40638_at 1p34.2	splicing factor proline/glutamine rich	SFPQ
25	66	40570_at 13q14.1	(polypyrimidine tract-binding protein-associated) forkhead box O1A (rhabdomyosarcoma)	FOXO1A
	67	40432_at	Homo sapiens, clone IMAGE:4391536, mRNA	
	68	39398_s_at 17q25.3	tubulin-specific chaperone d	TBCD
30	69	2003_s_at 2p16	mutS (E. coli) homolog 6	MSH6
	70	37561_at 6p12.1	Human DNA sequence from clone 34B21 on	
35	71	41038_at 1q25	chromosome neutrophil cytosolic factor 2	NCF2
	72	38402_at Xq24	lysosomal-associated membrane protein 2	LAMP2
40	73	37203_at 16q13- esterase 1) q22.1	carboxylesterase 1 (monocyte/macrophage serine CES1	
	74	34749_at 9q31-q32	solute carrier family 31 (copper transporters)	SLC31A2
45	75	40601_at 1p31.2	beta-amyloid binding protein precursor	BBP
	76	40194_at	Human chromosome 5q13.1 clone 5G8 mRNA	
	77	39566_at 15q14	cholinergic receptor, nicotinic, alpha polypeptide 7	CHRNA7
50	78	32706_at 22q11.21	HIR (histone cell cycle regulation defective)	HIRA

Table 53. Discriminating genes that distinguish between remission and fail overall derived from SVM analysis.

5		Affymetrix Locus number	Gene description	Gene symbol
10	1	41165_g_at 14q32.33	immunoglobulin heavy constant mu	IGHM
	2	39389_at 12p13	CD9 antigen (p24)	CD9
	3	41058_g_at 6p22.2	uncharacterized hypothalamus protein HT012	HT012
15	4	31459_i_at 22q11.1-	immunoglobulin lambda locus	IGL
		q11.2		
20	5	38389_at 12q24.1	2',5'-oligoadenylate synthetase 1 (40-46 kD)	OAS1
	6	37504_at 7q21.1-	E3 ubiquitin ligase SMURF1	SMURF1
25		q31.1		
	7	40367_at 20p12	bone morphogenetic protein 2	BMP2
	8	32637_r_at 16p12.3	PI-3-kinase-related kinase SMG-1	SMG1
30	9	39931_at 1q32	dual-specificity tyrosine-(Y)-phosphorylation	DYRK3
			regulated kinase 3	
	10	37054_at 20q11	bactericidal/permeability-increasing protein	BPI
35	11	1404_r_at 17q11.2-	small inducible cytokine A5 (RANTES)	SCYA5
		q12		
	12	1292_at 2q11	dual specificity phosphatase 2	DUSP2
40	13	37709_at Xp22.32	DNA segment, numerous copies	DXF68
	14	36857_at 5p13.2	RAD1 (S. pombe) homolog	RAD1
45	15	41196_at 17q21	karyopherin (importin) beta 1	KPNB1
	16	1182_at 2q33	phospholipase C, epsilon	PLCE
	17	34961_at 3q13.13	T cell activation, increased late expression	TACTILE
50	18	37862_at 1p31	dihydrolipoamide branched chain transacylase	DBT
			(E2 component of branched chain keto acid dehydrogenase complex; maple syrup disease)	
55	19	38772_at 1p31-	cysteine-rich, angiogenic inducer, 61	CYR61
		p22		

	20	33208_at 13q32	DnaJ (Hsp40) homolog, subfamily C, member 3	DNAJC3
	21	37837_at 18q23	KIAA0863 protein	KIAA0863
5	22	34031_i_at 7q21	cerebral cavernous malformations 1	CCM1
	23	38220_at 1p22	dihydropyrimidine dehydrogenase	DPYD
10	24	34684_at 12p12	RecQ protein-like (DNA helicase Q1-like)	RECQL
	25	39449_at 5p13	S-phase kinase-associated protein 2 (p45)	SKP2
	26	32638_s_at 16p12.3	PI-3-kinase-related kinase SMG-1	SMG1
15	27	35957_at 16p13	stannin	SNN
	28	34363_at 5q31	selenoprotein P, plasma, 1	SEPP1
20	29	35431_g_at 14q24.1	RNA polymerase II transcriptional regulation	MED6
	30	35012_at 1q22	mediator (Med6, <i>S. cerevisiae</i> , homolog of) myeloid cell nuclear differentiation antigen	MNDA
25	31	38432_at 1p36.33	interferon-stimulated protein, 15 kDa	ISG15
	32	35664_at 4q22	multimerin	MMRN
	33	41862_at 11q25	KIAA0056 protein	KIAA0056
30	34	33210_at 14q	YY1 transcription factor	YY1
	35	35794_at 8pter	KIAA0942 protein	KIAA0942
35	36	36108_at 6p21.3	HLA, class II, DQ beta 1	DQB1
	37	35614_at 20q13.3	transcription factor-like 5 (basic helix-loop-helix)	TCFL5
	38	32089_at 10p12	sperm associated antigen 6	SPAG6
40				

Table 53. (Continuation). Discriminating genes that distinguish between remissions and fails overall derived from SVM analysis.

45		Affymetrix Locus number	Gene description	Gene symbol
50	39	1343_s_at	serine (or cysteine) proteinase inhibitor)	SERPINB
		18q21.3		
	40	665_at	serine/threonine kinase 2	STK2
		3p21.1		
55	41	40901_at	nuclear autoantigen	GS2NA
		14q13		
	42	39299_at	KIAA0971 protein	KIAA0971
		2q34		

	43	34446_at 1q24	KIAA0471 gene product	KIAA0471
	44	33956_at 8q13.3	MD-2 protein	MD-2
5	45	37184_at 7q11.23	syntaxin 1A (brain)	STX1A
	46	1773_at 14q23	farnesyltransferase, CAAX box, beta	FNTB
10	47	34731_at 10q24.32	KIAA0185 protein	KIAA0185
	48	41700_at 5q13	coagulation factor II (thrombin) receptor	F2R
	49	38407_r_at 9q34.2	prostaglandin D2 synthase (21kD, brain)	GDS
15	50	40088_at 21q11.2	nuclear receptor interacting protein 1	NRIP1
	51	33124_at 2p16	vaccinia related kinase 2	VRK2
20	52	32964_at 19p13.3	egf-like module containing, mucin-like, hormone receptor-like sequence 1	EMR1
	53	39560_at 22q13.1	chromobox homolog 6	CBX6
25	54	39838_at 2q14.2	CLIP-associating protein 1	CLASP1
	55	40166_at	CS box-containing WD protein	LOC55884
	56	36927_at 1p22.3	hypothetical protein, expressed in osteoblast	GS3686
30	57	41393_at 11p15.5	zinc finger protein 195	ZNF195
	58	35041_at 12p13	neurotrophin 3	NTF3
35	59	40238_at 16p12	G protein-coupled receptor, family C, group 5,	GPRC5B
	60	39926_at 5q31	MAD (mothers against decapentaplegic, Drosoph)	MADH5
	61	36674_at 17q21	small inducible cytokine A4	SCYA4
40	62	32132_at 3q13.13	KIAA0675 gene product	KIAA0675
	63	38252_s_at 1p21	1,6-glucosidase, 4-alpha-glucanotransferase	AGL
45	64	33598_r_at 1q44	cold autoinflammatory syndrome 1	CIAS1
	65	37409_at 7q22	SFRS protein kinase 2	SRPK2
	66	41019_at 9q12	phosducin-like	PDCL
50	67	1113_at 20p12	bone morphogenetic protein 2	BMP2
	68	37208_at 7q11.2	phosphoserine phosphatase-like	PSPHL
55	69	32822_at 4q35	solute carrier family 25	SLC25A4
	70	32249_at 1q32	H factor (complement)-like 1	HFL1
	71	39600_at	EST	
60	72	32648_at 14q32	delta-like homolog (Drosophila)	DLK1

73	39269_at 13q12.3	replication factor C (activator 1) 3 (38kD)	RFC3
74	37724_at 8q24.12	v-myc avian myelocytomatosis viral oncogene	MYC
5 75	35606_at 15q21	histidine decarboxylase	HDC
76	31926_at 8q11	cytochrome P450, subfamily VIIA	CYP7A1
10 77	32142_at 8p22	serine/threonine kinase 3 (Ste20, yeast homolog)	STK3
78	32789_at 3q29	nuclear cap binding protein subunit 2, 20kD	NCBP2
79	37279_at 8q13	GTP-binding protein (skeletal muscle)	GEM
15 80	40246_at 3q29	discs, large (Drosophila) homolog 1	DLG1
81	37547_at 7p14	PTH-responsive osteosarcoma B1 protein	B1
20 82	32298_at 8p11.2	a disintegrin and metalloproteinase domain 2	ADAM2
83	40496_at 12p13	complement component 1, s subcomponent	C1S
84	39032_at 13q14	transforming growth factor beta-stimulated protein	TSC22
25			

Table 54. Discriminating genes that distinguish between remission and fail, inside the ALL type, derived from SVM.

30		Affymetrix Locus number	Gene description	Gene symbol
35	1	39389_at 12p13	CD9 antigen (p24)	CD9
	2	1292_at 2q11	dual specificity phosphatase 2	DUSP2
40	3	31459_i_at 22q11.1	immunoglobulin lambda locus	IGL
	4	36674_at 17q21	small inducible cytokine A4	SCYA4
	5	32637_r_at 16p12.3	PI-3-kinase-related kinase SMG-1	SMG1
45	6	35756_at 19p13.1	chromosome 19 open reading frame 3	C19orf3
	7	41700_at 5q13	coagulation factor II (thrombin) receptor	F2R
	8	31853_at 11q14.2	embryonic ectoderm development	EED
50	9	31329_at	putative opioid receptor, neuromedin K (neurokinin B) receptor-like	TAC3RL
	10	34491_at 12q24.2	2'-5'-oligoadenylate synthetase-like	OASL
55	11	34961_at 3q13.13	T cell activation, increased late expression	TACTILE
	12	160021_r_at 11q22	progesterone receptor	PGR

	13	37773_at 16	KIAA1005 protein	KIAA1005
	14	38367_s_at 1q32	complement component 4-binding protein, beta	C4BPB
5	15	32279_at 10p11	glutamate decarboxylase 2	GAD2
	16	36108_at 6p21.3	MHC complex, class II, DQ beta 1	DQB1
10	17	34378_at 9p21.3	adipose differentiation-related protein	ADFP
	18	777_at 10p15	GDP dissociation inhibitor 2	GDI2
	19	35140_at 13q12	cyclin-dependent kinase 8	CDK8
15	20	33208_at 13q32	DnaJ (Hsp40) homolog, subfamily C, member 3	DNAJC3
	21	33405_at 6p22.3	adenylyl cyclase-associated protein 2	CAP2
20	22	39580_at 9q34.3	KIAA0649 gene product	KIAA0649
	23	32469_at 19q13.2	carcinoembryonic antigen- cell adhesion 3	CEACAM
	24	38539_at 15q22	solute carrier family 24, member 1	SLC24A1
25	25	1454_at 15q21	MAD (mothers against decapentaplegic) 3	MADH3
	26	35289_at 9q34.11	rab6 GTPase activating protein	GPCENA
30	27	37724_at 8q24.12-	v-myc avian myelocytomatosis viral oncogene	MYC
	28	q24.13 32521_at 8p12	secreted frizzled-related protein 1	SFRP1
35	29	1375_s_at 17q25	tissue inhibitor of metalloproteinase 2	TIMP2
	30	555_at 17q25.3	GTP-binding protein homologous	SEC4
40	31	224_at 8q22.2	TGFB inducible early growth response	TIEG
	32	40367_at 20p12	bone morphogenetic protein 2	BMP2
	33	41504_s_at 16q22	v-maf aponeurotic fibrosarcoma oncogene	MAF
45	34	40166_at	CS box-containing WD protein	LOC55884
	35	35228_at 22q13	carnitine palmitoyltransferase I, muscle	CPT1B
50	36	33491_at 3q25.2	sucrase-isomaltase	SI
	37	1182_at 2q33	phospholipase C, epsilon	PLCE
	38	38869_at 3q25.31	KIAA1069 protein	KIAA1069
55	39	35811_at 3q25.1	ring finger protein 13	RNF13
	40	37504_at 7q21.1-	E3 ubiquitin ligase SMURF1	SMURF1
60		q31.1		

41	160025_at	transforming growth factor, alpha	TGFA
	2p13		
42	35233_r_at	centrin, EF-hand protein, 3 (CDC31 yeast)	CETN3
	5q14.3		
5 43	40399_r_at	mesenchyme homeo box 2 (growth arrest)	MEOX2
	7p22.1-		
	p21.3		

10 Table 54. (Continuation). Discriminating genes that distinguish between remission and fail, inside the ALL type, derived from SVM.

15	Affymetrix Locus number	Gene description	Gene symbol
44	31810_g_at	contactin 1	CNTN1
	12q11		
20 45	40789_at	adenylate kinase 2	AK2
	1p34		
46	35614_at	transcription factor-like 5 (basic helix-loop-helix)	TCFL5
	20q13.3		
47	34482_at	hypothetical protein MGC4701	MGC4701
25 48	4p16.3		
	34252_at	hypothetical protein FLJ10342	FLJ10342
	6q16.1		
49	32638_s_at	PI-3-kinase-related kinase SMG-1	SMG1
	16p12.3		
30 50	39440_f_at	mRNA (from clone DKFZp566H0124)	
51	1467_at	epidermal growth factor receptor substrate	EPS8
	12q23		
52	37500_at	zinc finger protein 175	ZNF175
	19q13.4		
35 53	1307_at	xeroderma pigmentosum, complement group A	XPA
	9q22.3		
54	1530_g_at	ESP	
55	37641_at	ESP	
56	36849_at	PTPL1-associated RhoGAP 1	PARG1 1
40 57	38797_at	KIAA0062 protein	KIAA0062
	8p21.2		
58	40510_at	heparan sulfate 2-O-sulfotransferase	HS2ST1
	1p31.1		
59	34168_at	deoxynucleotidyltransferase, terminal	DNTT
45 60	10q23-		
	q24		
	36682_at	pericentriolar material 1	PCM1
	8p22-		
50 61	p21.3		
	34335_at	ephrin-B2	EFNB2
	13q33		
62	41028_at	ryanodine receptor 3	RYR3
55 63	15q14-		
	q15		
	31434_at	Homo sapiens aconitase precursor (ACON) mRNA, nuclear gene encoding mitochondrial, partial cds	

64	35293_at	Sjogren syndrome antigen A2	SSA2
65	32987_at	FSH primary response (LRPR1, rat) homolog 1	FSHPRH1
5	66	34731_at	KIAA0185 protein
67	35102_at	zinc finger protein	ZFP
68	35664_at	multimerin	MMRN
10	69	32461_f_at	zinc finger protein 81 (HFZ20)
70	37864_s_at	immunoglobulin heavy constant gamma 3	IGHG3
15	71	37282_at	MAD2 (mitotic arrest deficient, yeast)-like 1
72	38407_r_at	prostaglandin D2 synthase (21kD, brain)	PTGDS
20	73	q34.3	homeo box A5
25	74	36539_at	Homo sapiens cDNA FLJ32313 fis, clone PROST 2003232, weakly similar to BETA-GLUCURONIDASE PRECURSOR (EC 3.2.1.31)
75	37602_at	guanidinoacetate N-methyltransferase	GAMT
30	76	38821_at	progesterone receptor membrane component 2
77	36248_at	NAG-5 protein	NAG5
78	33796_at	ADP-ribosylation factor-like 4	ARL4
35	79	37760_at	BAI1-associated protein 2
80	35299_at	MAP kinase-interacting serine/threonine kinase 1	MKNK1
40			

Table 55. Discriminating genes that distinguish between remission and fail, inside the AML type, derived from SVM analysis.

45	Affymetrix Locus number	Gene description	Gene symbol
50	1	32789_at	nuclear cap binding protein subunit 2, 20kD
2	39175_at	phosphofructokinase, platelet	PFKP
55	3	41058_g_at	uncharacterized hypothalamus protein HT012
4	38299_at	interleukin 6 (interferon, beta 2)	IL6

	5	41475_at 9q22	ninjurin 1	NINJ1
	6	38389_at 12q24.1	2',5'-oligoadenylate synthetase 1 (40-46 kD)	OAS1
5	7	35803_at 2q23.3	ras homolog gene family, member E	ARHE
	8	36419_at 11q13	phospholipase C, beta 3	PLCB3
10	9	32067_at 10p12.1	cAMP responsive element modulator	CREM
	10	39924_at 13q14	KIAA0853 protein	KIAA0853
	11	39246_at 3q22.3	stromal antigen 1	STAG1
15	12	38252_s_at 1p21	glycogen debranching enzyme (disease type III)	AGL
	13	35127_at 6p22.2	H2A histone family, member A	H2AFA
20	14	35486_at 12q21	Vertebrate LIN7, Tax interaction protein 33	VELI1
	15	1368_at 2q12	interleukin 1 receptor, type I	IL1R1
	16	40635_at 6p21.3	flotillin 1	FLOT1
25	17	1679_at 7q11	postmeiotic segregation increased 2-like 6	PMS2L6
	18	37354_at 2q37.1	nuclear antigen Sp100	SP100
30	19	1065_at 13q12	fms-related tyrosine kinase 3	FLT3
	20	41470_at 4p15.33	prominin (mouse)-like 1	PROML1
	21	37483_at 7p21p15	histone deacetylase 9	HDAC9-
35	22	34363_at 5q31	selenoprotein P, plasma, 1	SEPP1
	23	34631_at 6q23	eyes absent (Drosophila) homolog 4	EYA4
40	24	33124_at 2p16	vaccinia related kinase 2	VRK2
	25	39931_at 1q32	dual-specificity tyrosine-(Y)- kinase 3	DYRK3
	26	37185_at 18q21.3	serine (or cysteine) proteinase inhibitor	SERPINB
45	27	717_at 2p25.1	GS3955 protein	GS3955
	28	40305_r_at 1p31.1	phosphatidylinositol glycan, class K	PIGK
50	29	32636_f_at 16p12.3	PI-3-kinase-related kinase SMG-1	SMG1
	30	38052_at 6p25.3-	coagulation factor XIII, A1 polypeptide	F13A1
55	31	p24.3 772_at 17p13.3	v-crk avian sarcoma virus oncogene homolog	CRK
	32	41362_at 21q22.3	ATP-binding cassette, sub-family G (WHITE)	ABCG1
	33	36849_at	PTPL1-associated RhoGAP 1	PARG1

34	1451_s_at	osteoblast specific factor 2 (fasciclin I-like)	OSF-2
35	13q13.2		
35	37547_at	PTH-responsive osteosarcoma B1 protein	B1
5	7p14		
36	37504_at	E3 ubiquitin ligase SMURF1	SMURF1
	7q21.1		
37	33881_at	fatty-acid-Coenzyme A ligase, long-chain 3	FACL3
	2q34		
38	40439_at	arsA (bacterial) arsenite transporter, ATP-binding	ASNA1
10	19q13.3		
39	1914_at	cyclin A1	CCNA1
	13q12.3		
40	40928_at	DKFZP564A122 protein	DKFZP
	17q11.2		
15	41	36014_at	hypothetical protein DKFZp564D0462
	6q23.1		
42	34355_at	methyl CpG binding protein 2 (Rett syndrome)	MECP2
	Xq28		
43	38096_f_at	MHC, class II, DP beta 1	DPB1
20	6p21.3		
44	32298_at	a disintegrin and metalloproteinase domain 2	ADAM2
	8p11.2		
45	35699_at	budding uninhibited by benzimidazoles 1	BUB1B
	15q15		
25	46	41165_g_at	immunoglobulin heavy constant mu
	14q32		

Table 55. (Continuation). Discriminating genes that distinguish between remission and fail, inside the AML type, derived from SVM analysis.

30

	Affymetrix Locus number	Gene description	Gene symbol
35			
47	35422_at	microtubule-associated protein 2	MAP2
	2q34		
48	41471_at	S100 calcium-binding protein A9 (calgranulin B)	S100A9
40	1q21		
49	34761_r_at	a disintegrin and metalloproteinase domain 9	ADAM9
50	31786_at	Sam68-like phosphotyrosine protein, T-STAR	T-STAR
	8q24.2		
51	40318_at	dynein, cytoplasmic, intermediate polypeptide 1	DNCI1
45	7q21.3		
52	40497_at	homologous to yeast nitrogen permease	NPR2L
	3p21.3		
53	34728_g_at	S-adenosylhomocysteine hydrolase-like 1	AHCYL1 1
54	36857_at	RAD1 (S. pombe) homolog	RAD1
50	5p13.2		
55	39449_at	bleomycin hydrolase	BLMH
	17q11.2		
56	40498_g_at	homologous to yeast nitrogen permease	NPR2L
	3p21.3		
55	57	37936_at	PRP4/STK/WD splicing factor
	9q31		
58	34891_at	dynein, cytoplasmic, light polypeptide	PIN
	14q24		

	59	39061_at	bone marrow stromal cell antigen 2	BST2
	60	34446_at	KIAA0471 gene product	KIAA0471
5	61	37456_at	serum constituent protein	MSE55
	62	41385_at	erythrocyte membrane protein band 4.1-like 3	EPB41L3
10	63	990_at	fms-related tyrosine kinase 1 (vascular endothelial FLT1	
	64	37203_at	growth factor/vascular permeability factor receptor) carboxylesterase 1	CES1
15	65	40071_at	cytochrome P450, subfamily I	CYP1B1
	66	1491_at	pentaxin-related gene, induced by IL-1 beta	PTX3
	67	31558_at	Hr44 antigen	HR44
20	68	761_g_at	dual-specificity tyrosine-(Y)-phosphorylation	DYRK2
	69	32607_at	regulated kinase 2	
	70	32305_at	brain abundant, membrane signal protein 1	BASP1
25	71	531_at	collagen, type I, alpha 2	COL1A2
	72	40901_at	glioma pathogenesis-related protein	RTVP1
	73	35609_at	nuclear autoantigen	GS2NA
30	74	40851_r_at	protocadherin gamma subfamily A, 8	PCDHGA8
	75	41022_r_at	Sec23 (S. cerevisiae) homolog B	SEC23B
35	76	40853_at	glycerol-3-phosphate dehydrogenase 2	GPD2
	77	38555_at	ATPase, Class V, type 10D	ATP10D
	78	41393_at	dual specificity phosphatase 10	DUSP10
40	79	32089_at	zinc finger protein 195	ZNF195
	80	32072_at	sperm associated antigen 6	SPAG6
45	81	394_at	mesothelin	MSLN
	82	32605_r_at	S-phase kinase-associated protein 2 (p45)	SKP2
	83	31665_s_at	RAB1, member RAS oncogene family	RAB1
50	84	35940_at	CDA02 protein	CDA02
	85	37469_at	POU domain, class 4, transcription factor 1	POU4F1
55	86	32599_at	Rough Deal (Drosophila) homolog	KIAA0166
	87	33894_at	tuberous sclerosis 1	TSC1
			neuroepithelial cell transforming gene 1	NET1

Table 56. Discriminating genes that distinguish between remission and fail, inside the *VxInsight* cluster A, derived from Bayesian Networks and SVM analysis.

A. Bayesian Networks				
		Affymetrix Locus number	Gene description	Gene symbol
1	1	1247_g_at 19p13.3	protein tyrosine phosphatase, receptor type, S	PTPRS
15	2	128_at 1q21	cathepsin K (pseudosclerosis)	CTSK
	3	1445_at 3p21	chemokine (C-C motif) receptor-like 2	CCRL2
20	4	1509_at 8q21	matrix metalloproteinase 16 (membrane-inserted)	MMP16
	5	1523_g_at 17p13.1	tyrosine kinase, non-receptor, 1	TNK1
25	6	1578_g_at Xq11.2-	androgen receptor (dihydrotestosterone receptor; testicular feminization; spinal and bulbar muscular atrophy; Kennedy disease)	AR
	7	158_at 1p22.3	DnaJ (Hsp40) homolog, subfamily B, member 4	DNAJB4
30	8	1777_at 11q13.1	ras inhibitor	RIN1
	9	31375_at 10q23.3	ADP-ribosylation factor-like 3	ARL3
35	10	31440_at 5q31.1	transcription factor 7 (T-cell specific, HMG-box)	TCF7
	11	31552_at	Homo sapiens low density lipoprotein receptor	
	12	31713_s_at 8p23	large (Drosophila) homolog-associated protein 2	DLGAP2
40	13	31996_at 20q13	brefeldin A-inhibited guanine nucleotide-exchange 2	BIG2
	14	32029_at 16p13.3	3-phosphoinositide dependent protein kinase-1	PDPK1
	15	32823_at 11q23	vacuolar protein sorting 11 (yeast homolog)	VPS11
45	16	32903_at 9q22	transforming growth factor, beta receptor I	TGFBR1
	17	33019_at 6q25.2	Parkinson disease (autosomal recessive, juvenile)	PARK2
50	18	33280_r_at 16p13.11	SA (rat hypertension-associated) homolog	SAH
	19	34110_g_at	proline oxidase homolog	PIG6
	20	34124_at 6q25	similar to prokaryotic-type class I peptide chain	LOC16
55	21	34181_at 4q32	release factors aspartylglucosaminidase	AGA
	22	35044_i_at 1p35	bone morphogenetic protein 8 (osteogenic 2)	BMP8

23	35375_at Xp11.23	apurinic/apyrimidinic endonuclease(nuclease)	APEXL2
24	35942_at 7q11.2	GA-binding protein transcription factor, beta 1	GABPB1

5

Table 56. (Continuation). Discriminating genes that distinguish between remission and fail, inside the *VxInsight* cluster A, derived from SVM analysis.

10

B. SVM			
	Affymetrix Locus number	Gene description	Gene symbol
1	39389_at 12p13.3	CD9 antigen (p24)	CD9
2	1292_at 2q11	dual specificity phosphatase 2	DUSP2
3	36674_at 17q12	small inducible cytokine A4	SCYA4
4	32637_r_at 16p13.2	PI-3-kinase-related kinase SMG-1	SMG1
5	35756_at 19p13.1	regulator of G-protein signalling 19 interacting	RGS19IP1
6	41700_at 5q13	coagulation factor II (thrombin) receptor	F2R
7	31853_at 11q14	embryonic ectoderm development	EED
8	31329_at	Human putative opioid receptor mRNA, complete	
9	34491_at 12q24.2	2'-5'-oligoadenylate synthetase-like	OASL
10	34961_at 3q13.2	T cell activation, increased late expression	TACTILE
11	160021_r_at 11q22-q23	progesterone receptor	PGR
12	38367_s_at 1q32	complement component 4 binding protein, beta	C4BPB
13	32279_at 10p11.23	glutamate decarboxylase 2 (pancreas and brain)	GAD2
14	36108_at 6p21.3	MHC, class II, DQ beta 1	DQB1
15	34378_at 9p21.2	adipose differentiation-related protein	ADFP
16	777_at 10p15	GDP dissociation inhibitor 2	GDI2
17	35140_at 13q12	cyclin-dependent kinase 8	CDK8
18	33208_at 13q32	DnaJ (Hsp40) homolog, subfamily C, member 3	DNAJC3
19	33405_at 6p22.2	adenylyl cyclase-associated protein 2	CAP2
20	39580_at 9q34.3	KIAA0649 gene product	KIAA0649
21	32469_at 19q13.2	carcinoembryonic antigen-related cell adhesion	CEACAM

22	38539_at	solute carrier family 24	SLC24A1
	15q22		
23	33739_at	Homo sapiens mRNA full length insert cDNA	
24	1454_at	MAD, mothers against decapentaplegic 3	MADH3
5	15q21-q22		
25	35289_at	rab6 GTPase activating protein	CENA
	9q34.11		
26	37724_at	v-myc myelocytomatosis viral oncogene homolog	MYC
	8q24.12		
10	27	secreted frizzled-related protein 1	SFRP1
	8p12-p11.1		
28	1375_s_at	tissue inhibitor of metalloproteinase 2	TIMP2
	17q25		
29	615_s_at	parathyroid hormone-like hormone	PTHLH
15	12p12.1		
30	555_at	RAB40B, member RAS oncogene family	RAB40B
	17q25.3		
31	224_at	TGFB inducible early growth response	TIEG
	8q22.2		
20	32	bone morphogenetic protein 2	BMP2
	20p12		
33	37380_at	general transcription factor IIB	GTF2B
	1p22-p21		
34	41504_s_at	v-maf aponeurotic fibrosarcoma oncogene	MAF
25	16q22-q23		
35	40166_at	CS box-containing WD protein	LOC55
36	35228_at	carnitine palmitoyltransferase I, muscle	CPT1B
	22q13.33		
37	36113_s_at	troponin T1, skeletal, slow	TNNT1
30	19q13.4		
38	33491_at	sucrase-isomaltase	SI
	3q25.2		
39	1182_at	phospholipase C-like 1	PLCL1
	2q33		
35	40	KIAA1069 protein	KIAA1069
	3q26.1		
41	35811_at	ring finger protein 13	RNF13
	3q25.1		
42	33186_i_at	ESTs	
40	43	E3 ubiquitin ligase SMURF1	SMURF1
	7q21.1		
44	160025_at	transforming growth factor, alpha	TGFA
	2p13		

45 Table 56. (Continuation). Discriminating genes that distinguish between remission and fail, inside the *VxInsight* cluster A, derived from SVM analysis.

50	Affymetrix Locus number	Gene description	Gene symbol
45	32684_at	Homo sapiens clone 23579 mRNA sequence	
55	46	centrin, EF-hand protein, 3 (CDC31 homolog)	CETN3
	5q14.3		
47	40399_r_at	mesenchyme homeo box 2 (growth arrest)	MEOX2
	7p22.1		

	48	36777_at	DNA segment on chromosome 12 (unique)	2489	D12S
	49	31810_g_at	contactin 1		CNTN1
5	50	33747_s_at	RNA, U17D small nucleolar		RNU17D
	51	37577_at	hypothetical protein MGC14258		MGC
10	52	40789_at	adenylate kinase 2		AK2
	53	34855_at	hypothetical protein MGC5378		MGC5378
	54	35614_at	transcription factor-like 5 (basic helix-loop-helix)		TCFL5
15	55	34482_at	hypothetical protein MGC4701		MGC4701
	56	37220_at	Fc fragment of IgG, receptor for - CD64		FCGR1A
20	57	36444_s_at	small inducible cytokine subfamily A		SCYA23
	58	34252_at	hypothetical protein FLJ10342		FLJ10342
	59	32638_s_at	PI-3-kinase-related kinase SMG-1		SMG1
25	60	1467_at	epidermal growth factor receptor 8		EPS8
	61	37500_at	zinc finger protein 175		ZNF175
30	62	1307_at	xeroderma pigmentosum, complement group A		XPA
	63	1530_g_at	hypothetical protein CG003		13CDNA
	64	37641_at	interferon-induced protein 44		IFI44
35	65	36849_at	PTPL1-associated RhoGAP 1		PARG1
	66	38797_at	KIAA0062 protein		KIAA0062
40	67	40510_at	heparan sulfate 2-O-sulfotransferase 1		HS2ST1
	68	34168_at	deoxynucleotidyltransferase, terminal		DNTT
	69	36682_at	pericentriolar material 1		PCM1
45	70	34335_at	ephrin-B2		EFNB2
	71	40549_at	cyclin-dependent kinase 5		CDK5
50	72	41028_at	ryanodine receptor 3		RYR3
	73	31434_at	Homo sapiens aconitase precursor (ACON)		
	74	33031_at	Homo sapiens mRNA full length insert cDNA clone		
	75	35293_at	Sjogren syndrome antigen A2 (60kD)		SSA2
55	76	32987_at	FSH primary response (LRPR1 homolog, rat) 1		FSHPRH1
	77	34731_at	KIAA0185 protein		KIAA0185
60	78	35102_at	zinc finger protein		ZFP

	79	35664_at 4q22	multimerin	MMRN
	80	34208_at 20q13.12	solute carrier family 12, member 5	SLC12A5
5	81	37864_s_at 14q32.33	immunoglobulin heavy constant gamma 3	IGHG3
	82	37282_at 4q27	MAD2 mitotic arrest deficient-like 1 (yeast)	MAD2L1
10	83	38407_r_at 9q34.2	prostaglandin D2 synthase (21kD, brain)	PTGDS
	84	37602_at 19p13.3	guanidinoacetate N-methyltransferase	GAMT
	85	38821_at 4q26	progesterone receptor membrane component 2	PGRMC2
15	86	36248_at 9p11.2	NAG-5 protein	NAG5
	87	33796_at 12q13	epithelial protein lost in neoplasm beta	EPLIN
20	88	37760_at 17q25	BAI1-associated protein 2	BAIAP2
	89	35299_at 1p34.1	MAP kinase-interacting serine/threonine kinase 1	MKNK1

Table 57. Discriminating genes that distinguish between remission and fail, inside the *VxInsight* cluster C, derived from Bayesian Networks and SVM analysis.

A. Bayesian Networks				
		Affymetrix Locus number	Gene description	Gene symbol
30				
35	1	111_at 14q11.2	Rab geranylgeranyltransferase, alpha subunit	RAB
	3	1274_s_at 19p13.3	cell division cycle 34	CDC34
40	4	1561_at 11p15.5	dual specificity phosphatase 8	DUSP8
	6	31405_at 11q21-q22	melatonin receptor 1B	MTNR1B
	7	31803_at 21q22.3	KIAA0653 protein, B7-like protein	KIAA0653
45	8	32334_f_at 12q24.3	ubiquitin C	UBC
	9	32892_at 6q27	ribosomal protein S6 kinase, 90kD	RPS6KA2
50	10	33095_i_at 3q21-q25	beaded filament structural protein 2, phakinin	BFSP2
	11	33293_at 12q13	lifeguard	KIAA0950
	12	34913_at 1q32	calcium channel, voltage-dependent, L type	CACNA1S
55	13	35957_at 16p13	stannin	SNN
	14	36038_r_at 14q23	spectrin, beta, erythrocytic	SPTB

15	36342_r_at	H factor (complement)-like 3	HFL3
	1q31-q32.1		
16	37596_at	phospholipase C, delta 1	PLCD1
	3p22-p21.3		
5 17	38299_at	interleukin 6 (interferon, beta 2)	IL6
	7p21		
18	41520_at	hypothetical protein	LOC56148
19	772_at	v-crk avian sarcoma virus CT10 oncogene	CRK
	17p13.3		
10 20	1001_at	tyrosine kinase with immunoglobulin and	TIE
	1p34-p33		
		epidermal growth factor homology domains	
21	1707_g_at	v-raf murine sarcoma viral oncogene homolog	ARAF1
	Xp11.4-		
15	p11.2		
22	1719_at	mutS (E. coli) homolog 3	MSH3
	5q11-q12		
23	1962_at	arginase, liver	ARG1
20	6q23		
24	2034_s_at	cyclin-dependent kinase inhibitor 1B	CDKN1B
	12p13.1		
25	31505_at	ribosomal protein L8	RPL8
	8q24.3		
25			

Table 57. (Continuation). Discriminating genes that distinguish between remission and fail, inside the *VxInsight* cluster C, derived from SVM analysis.

30	B. SVM		
	Affymetrix Locus number	Gene description	Gene symbol
35			
	1 914_g_at	v-ets erythroblastosis virus E26 oncogene like	ERG
		21q22.3	
	2 32789_at	nuclear cap binding protein subunit 2, 20kD	NCBP2
40		3q29	
	3 38299_at	interleukin 6 (interferon, beta 2)	IL6
		7p21	
	4 39175_at	phosphofructokinase, platelet	PFKP
		10p15.3	
45	5 1368_at	interleukin 1 receptor, type I	IL1R1
		2q12	
	6 41219_at	Homo sapiens mRNA; cDNA DKFZp586J101	
	7 38389_at	2',5'-oligoadenylate synthetase 1 (40-46 kD)	OAS1
		12q24.1	
50	8 32067_at	cAMP responsive element modulator	CREM
		10p12.1	
	9 41058_g_at	uncharacterized hypothalamus protein HT012	HT012
		6p21.32	
	10 41425_at	Friend leukemia virus integration 1	FLI1
55		11q24.1	
	11 33124_at	vaccinia related kinase 2	VRK2
		2p16-p15	

	12	41475_at	ninjurin 1	NINJ1
		9q22		
	13	38866_at	EST	
	14	35803_at	ras homolog gene family, member E	ARHE
5		2q23.3		
	15	41096_at	S100 calcium binding protein A8 (calgranulin A)	S100A8
		1q21		
	16	33800_at	adenylate cyclase 9	ADCY9
		16p13.3		
10	17	37143_s_at	phosphoribosylformylglycinamide synthase	PFAS
		17p13		
	18	37535_at	cAMP responsive element binding protein 1	CREB1
		2q32.3-q34		
	19	38253_at	amylase-1, 6-glucosidase, 4-alpha-	AGL
15		1p21		
	20	36857_at	RAD1 homolog (S. pombe)	RAD1
		5p13.2		
	21	39931_at	dual-specificity tyrosine-(Y)-phosphorylation	DYRK3
		1q32		
20			regulated kinase 3	
	22	772_at	v-crk sarcoma virus CT10 oncogene homolog	CRK
		17p13.3		
	23	35957_at	stannin	SNN
		16p13		
25	24	41755_at	KIAA0977 protein	KIAA0977
		2q24.3		
	25	31786_at	RNA binding, signal transduction associated 3	KHDRBS3
		8q24.2		
	26	35127_at	H2A histone family, member A	H2AFA
30		6p22.		
	27	40928_at	SOCS box-containing WD protein SWiP-1	WSB1
		17q11.1		
	28	32636_f_at	PI-3-kinase-related kinase SMG-1	SMG1
		16p13.2		
35	29	531_at	glioma pathogenesis-related protein	RTVP1
		12q14.1		
	30	35860_r_at	ESTs	
	31	41471_at	S100 calcium binding protein A9 (calgranulin B)	S100A9
		1q21		
40	32	35582_at	ESTs	
	33	39878_at	protocadherin 9	PCDH9
		13q14.3		
	34	37504_at	E3 ubiquitin ligase SMURF1	SMURF1
		7q21.1		
45	33	34965_at	cystatin F (leukocystatin)	CST7
		20p11.21		
	34	37050_r_at	translocase of outer mitochondrial membrane 34	TOMM34
	35	32034_at	zinc finger protein 217	ZNF217
		20q13.2		
50	36	33104_at	PH domain containing protein in retina 1	PHRET1
		11q13.5		
	37	40318_at	dynein, cytoplasmic, intermediate polypeptide 1	DNCI1
		7q21.3		
	38	34387_at	KIAA0205 gene product	KIAA0205
55		1p36.13		
	39	37208_at	phosphoserine phosphatase-like	PSPHL
		7q11.2		
	40	38139_at	fucose-1-phosphate guanylyltransferase	FPGT
		1p31.1		

41	1914_at 13q12.3	cyclin A1	CCNA1
42	717_at 2p25.1	GS3955 protein	GS3955

5

Table 57. (Continuation). Discriminating genes that distinguish between remission and fail, inside the *VxInsight* cluster C, derived from SVM analysis.

10		Affymetrix Locus number	Gene description	Gene symbol
15	43	36123_at 22q13.1	thiosulfate sulfurtransferase (rhodanese)	TST
	44	33881_at 2q34-q35	fatty-acid-Coenzyme A ligase, long-chain 3	FACL3
	45	35606_at 15q21-q22	histidine decarboxylase	HDC
20	46	36478_at 9q34.3	transcription termination factor, RNA polymerase I	TTF1
	47	34363_at 5q31	selenoprotein P, plasma, 1	SEPP1
25	48	34631_at 6q23	eyes absent homolog 4 (Drosophila)	EYA4
	49	37773_at 16q12.2	KIAA1005 protein	KIAA1005
	50	1451_s_at 13q13.2	osteoblast specific factor 2 (fascin I-like)	OSF-2
30	51	40635_at 6p21.3	flotillin 1	FLOT1
	52	34961_at 3q13.2	T cell activation, increased late expression	TACTILE
35	53	32637_r_at 16p13.2	PI-3-kinase-related kinase SMG-1	SMG1
	54	1808_s_at 10q24.1	tumor necrosis factor receptor superfamily, 6	TNFRSF6
	55	1369_s_at 4q13-q21	interleukin 8	IL8
40	56	35614_at 20q13.3	transcription factor-like 5 (basic helix-loop-helix)	TCFL5
	57	40511_at 10p15	GATA binding protein 3	GATA3
45	58	1229_at 1q12-q21	cisplatin resistance associated	CRA
	59	34247_at 4q25-q26	protease, serine, 12 (neurotrypsin, motopsin)	PRSS12
	60	35980_at 20p12	phospholipase C, beta 1	PLCB1
50	61	33715_r_at 5q12.2	general transcription factor IIH, polypeptide 2	GTF2H2
	62	852_at 17q21.32	integrin, beta 3	ITGB3
55	63	1913_at 4q13.3	cyclin G2	CCNG2
	64	36569_at 3p22-p21.3	tetranectin (plasminogen binding protein)	TNA

	65	41708_at	KIAA1034 protein	KIAA1034
		2q33		
	66	41348_at	iroquois homeobox protein 5	IRX5
		16q11.2		
5	67	38952_s_at	collagen, type XIII, alpha 1	COL13A1
		10q22		
	68	33553_r_at	chemokine (C-C motif) receptor 6	CCR6
		6q27		
10	69	41165_g_at	immunoglobulin heavy constant mu	IGHM
		14q32.33		
	70	34435_at	aquaporin 9	AQP9
		15q22.1		
	71	1679_at	postmeiotic segregation increased 2-like 6	PMS2L6
		7q11-q22		
15	72	41742_s_at	optineurin	OPTN
		10p12.33		
	73	36998_s_at	spinocerebellar ataxia 2	SCA2
		12q24		
20	74	39032_at	transforming growth factor beta-stimulated protein	TSC22
		13q14		
	75	1065_at	fms-related tyrosine kinase 3	FLT3
		13q12		
	76	40584_at	nucleoporin 88kD	NUP88
		17p13		
25	77	41470_at	prominin-like 1 (mouse)	PROML1
		4p15.33		
	78	38470_i_at	amyloid beta precursor protein	APPBP2
		17q21-q23		
	79	37676_at	phosphodiesterase 8A	PDE8A
30		15q25.1		
	80	35449_at	killer cell lectin-like receptor B, member 1	KLRB1
		12p13		
	81	36474_at	KIAA0776 protein	KIAA0776
		6q16.3		
35	82	32142_at	serine/threonine kinase 3 (STE20 homolog, yeast)	STK3
		8q22.1		
	83	39299_at	KIAA0971 protein	KIAA0971
		2q33.3		
40	84	38252_s_at	1, 6-glucosidase, 4-alpha-glucanotransferase	AGL
		1p21		
	85	39246_at	stromal antigen 1	STAG1
		3q22.3		
	86	160030_at	growth hormone receptor	GHR
		5p13-p12		
45	87	33736_at	stomatin (EBP72)-like 1	STOML1
		15q24-q25		
	88	36014_at	hypothetical protein DKFZp564D0462	DKFZP56
		6q23.1		
50	89	32072_at	mesothelin	MSLN
		16p13.12		

6. Additional explorations on VxInsight clustering results with the Genetic Algorithm K-Nearest Neighbor method (GA/KNN).

As it was previously mentioned, the *VxInsight* clustering algorithm identified three major groups, A, B, and C, in the infant leukemia dataset. We

hypothesized these groups correspond to distinct biologic clusters, correlated with unique disease etiologies. Several approaches were used to evaluate cluster stability and to determine genes that discriminate between the clusters. In order to test how well these three clusters can be distinguished using
5 *supervised* classification and cross-validation methods (49) we used a genetic algorithm training methodology to perform feature selection using a simple K-nearest neighbor classifier (50, 51). This approach was applied using *VxInsight* cluster train/test class labels, creating three implied one-vs.-all classification problems (A vs. B+C, etc.) The "top 50" discriminating gene lists are reported
10 for each problem, and compared with previously obtained ANOVA gene lists.

To compare this "top 50" gene lists with the gene lists generated using ANOVA, we used a one-vs-all-others (OVA) approach to form three binary classification problems: a) A vs. BC; b) B vs. CA; c) C vs. AB. Based on our subsequent numerical results (time to solution for the genetic algorithm), Task
15 (a) appears to have been the easiest and Task (b) the hardest. We also did three-way classification for *VxInsight* groups. It is Task (d).

6.1. GA/KNN procedure and parallel program parameters

The Genetic Algorithm (GA) K Nearest Neighbor (KNN) method (50,
20 51) is a supervised feature selection method based on the non-parametric k-nearest neighbor classification approach (52). GA uses a direct analogy of natural behavior and works with a "population" of "chromosomes." Each chromosome represents a possible solution to a given problem. A chromosome is assigned a fitness score according to how good a solution to the problem it is.
25 Highly fit individuals are given opportunities to "reproduce," by "cross breeding" with other individuals in the population. This produces new individuals (offspring), which share some features taken from each parent. The least fit members of the population are less likely to get selected for reproduction, and so die out. Selecting the best individuals from the current
30 "generation" and mating them to produce a new set of individuals produce an entirely new population of possible solutions. This new generation contains a higher proportion of the characteristics possessed by the good members of the previous generation. In this way, over many generations, good characteristics

are spread throughout the population, being mixed and exchanged with other good characteristics. The fitness of each chromosome is determined by its ability to classify the training set samples according to the KNN procedure. In KNN, each sample was classified according to its k nearest neighbors, using the

5 Euclidean distance metric in d -dimensional space (d is the number of probesets in the expression profile for a given patient sample). In our initial experiments, we have chosen $k=3$. In consensus rule, if all of the k nearest neighbors of a sample belong to the same class, the sample is classified as that class; otherwise, the sample is considered unclassifiable. In majority rule, if more than

10 half of the k nearest neighbors of a sample belong to the same class, the sample is classified as that class; otherwise, the sample is considered unclassifiable.

The GA/KNN methodology was implemented as a C/MPI parallel program on the LosLobos Linux supercluster. The program terminates when 2000 good solutions have been obtained. Following this initial processing, the

15 frequency with which each probeset was selected was analyzed.

The parameters used were as follows:

- Number of independent GA runs: 2000
- Number of generations/run: 1000

20 ◦ Number of chromosomes in population: 100

- Number of genes in each chromosome: 20
- Number of neighbors (k) in KNN: 3
- KNN rules: consensus in training; majority in test
- Number of parallel compute nodes (2 processors/node): 26

25 ◦ Number of master nodes: 1

- Number of slave processes: 50

6.2. Methods

1) *Select predictor probesets*

30 Using the *VxInsight* cluster labels, we applied the GA/KNN methodology to select the top 50 discriminating probesets from the initial list of 8446 probesets for each task. Here we used consensus rule.

2) *Compare with VxInsight cluster-characterizing genes*

The *VxInsight* clustering algorithm identified 126 cluster-characterizing genes for each task according to the F values in ANOVA. The lists include top up-regulated and down-regulated genes. Here we compared them with our

5 predictor probesets.

3) *Evaluate classifier performance*

Both leave-one-out cross validation (LOOCV) and evaluation on an independent test set were used to evaluate classifier performance for the *VxInsight* clusters. Note that we have made no attempt at this stage to

10 optimize—using the training set only, and blinded to the test set—the number of features selected for the final out-of-sample test set evaluation. Here LOOCV based on consensus rule and prediction for test dataset based on majority rule.

4) *Statistical significance analysis*

The statistical significance of the predictions was calculated. We tested whether
15 the Success Rate (SR) was larger than 0.5 and whether the Odds Ratio (OR=TP/FP) was larger than 1.

6.3. Results

1) *Top gene selections*--Z-score plots were computed from gene selection frequencies in the GA (see (50, 51) for details). A very high Z-score
20 gene "40103_at" was found for cluster B vs. CA and C vs. AB.

2) *Top gene lists*-- Tables 58 (A vs. BC), 59 (B vs. CA) and 60 (C vs. AB) show the overlap with 'up'- and 'down'-regulated gene lists in the infant cohort as indicated. The numbers of overlapping genes between the cluster-characterizing genes and our top 50 genes are 20, 17, and 17 for
25 A vs. BC, B vs. CA, and C vs. AB tasks respectively.

3) *Evaluating the performance of a classifier*

See Table 61. Here *pVal1* is p-value of testing whether the SR is larger than 0.5 and *pVal2* is p-value of testing whether the OR is larger than 1. Both *pVal1s* and *pVal2s* are very small (<0.05) for our predictions. So they are significant.

30

4) *Classification results with DIFF genes*

The numbers of DIFF calls are 46, 32, and 36 in top 50 discriminating genes, for A vs. BC, B vs. CA, and C vs. AB respectively. We did classification
5 only based on DIFF genes, for A vs. BC, B vs. CA, and C vs. AB respectively.
Unfortunately, no improvement of SRs was observed for test dataset (Table 62).

Table 58: Top gene list for Cluster A vs. BC

Rank	Affx Num	Gene description	Z-score	Paper		H/L	High%	Low%
				List	Rank			
1	31497_at	G antigen 2	180.92			L	20.2	79.8
2	40539_at	myosin IXB	134.92	up	10	L	14.6	85.4
3	31829_r_at	trans-golgi network protein 2	86.15			L	20.2	79.8
4	34573_at	ephrin-A3	65.45	up	15	L	18.0	82.0
5	34415_at	activin A receptor, type IB	65.45			L	18.0	82.0
6	34970_r_at	5-oxoprolinase (ATP-hydrolysing)	58.09			L	18.0	82.0
7	1280_i_at	NO_SIF_seq	55.33			L	19.1	80.9
8	39306_at	protease, serine, 16 (thymus)	52.57	up	28	L	16.9	83.2
9	41374_at	ribosomal protein S6 kinase, 70kD, polypeptide 2	51.65			L	16.9	83.2
10	39775_at	serine (or cysteine) proteinase inhibitor, clade G (C1 inhibitor), member 1	45.67	up	17	L	24.7	75.3
11	36276_at	contactin 2 (axonal)	37.85	up	2	L	23.6	76.4
12	32104_l_at	calcium/calmodulin-dependent protein kinase (CaM kinase) II gamma	34.17			L	23.6	76.4
13	36991_at	splicing factor, arginine/serine-rich 4	32.33	down	1	H	73.0	27.0
14	1925_at	cyclin F	30.95	up	29	L	18.0	82.0
15	35571_at	coagulation factor II (thrombin) receptor-like 3	28.64			L	19.1	80.9
16	538_at	CD34 antigen	28.18	up	36	L	36.0	64.0
17	34755_at	ADP-ribosyltransferase (NAD ⁺ ; poly(ADP-ribose) polymerase)-like 2	26.34			L	20.2	79.8
18	33034_at	rhomboid (veinlet, Drosophila)-like	25.88	up	33	L	13.5	86.5
19	33338_at	signal transducer and activator of transcription 1, 91kD	23.58			H	74.2	25.8
20	396_f_at	erythropoietin receptor	21.28	up	6	L	23.6	76.4
21	34949_at	KIAA1048 protein	20.36			L	25.8	74.2
22	31508_at	thioredoxin interacting protein	19.90			H	68.5	31.5
23	41101_at	KIAA0274 gene product	19.44			L	27.0	73.0
24	884_at	integrin, alpha 3 (antigen CD49C, alpha 3 subunit of VLA-3 receptor)	17.60	up	9	L	29.2	70.8
25	838_s_at	ubiquitin-conjugating enzyme E2I (homologous to yeast UBC9)	17.60			H	71.9	28.1
26	41749_at	ES1 (zebrafish) protein, human homolog of	17.14			H	69.7	30.3
27	33516_at	hemoglobin, delta	17.14			L	31.5	68.5
28	41206_r_at	cytochrome c oxidase subunit VIa polypeptide 1	16.68			H	58.4	41.6
29	1357_at	ubiquitin specific protease 4 (proto-oncogene)	16.68	down	11	H	84.3	15.7
30	41734_at	KIAA0870 protein	16.22			H	79.8	20.2
31	39196_i_at	ortholog of mouse integral membrane glycoprotein LIG-1	16.22			L	23.6	76.4
32	37341_at	glutamate dehydrogenase 1	16.22			L	24.7	75.3
33	41264_at	Homo sapiens mRNA; cDNA DKFZp586F1322 (from clone DKFZp586F1322)	15.76			L	20.2	79.8
34	35503_at	5-hydroxytryptamine (serotonin) receptor 1B	15.76			L	25.8	74.2

Rank	Affx Num	Gene description	Z-score	Paper		126	H/L	High%	Low%
				List	Rank				
35	33470_at	KIAA1719 protein	15.76			11	L	25.8	74.2
36	459_s_at	bridging integrator 1	15.30				H	67.4	32.6
37	37203_at	carboxylesterase 1 (monocyte/macrophage serine esterase 1)	15.30				H	61.8	38.2
38	1653_at	ribosomal protein S3A	15.30				L	44.9	55.1
39	1052_s_at	CCAAT/enhancer binding protein (C/EBP), delta	15.30				L	29.2	70.8
40	40830_at	DnaJ (Hsp40) homolog, subfamily C, member 4	14.84				L	25.8	74.2
41	38648_at	trinucleotide repeat containing 1	14.84				H	67.4	32.6
42	32878_f_at	Homo sapiens cDNA FLJ32819 fis, clone TEST12002937, weakly similar to HISTONE H3.2	14.38				H	84.3	15.7
43	40941_at	VAMP (vesicle-associated membrane protein)-associated protein B and C	13.92				L	11.2	88.8
44	38530_at	hypothetical protein FLJ22709	13.46				L	19.1	80.9
45	35355_at	Homo sapiens cDNA FLJ11214 fis, clone PLACE1007990	13.46				H	64.0	36.0
46	40501_s_at	myosin-binding protein C, slow-type	13.00	up	30	68	L	19.1	80.9
47	36242_at	small proline-rich protein 2C	12.08			82	L	27.0	73.0
48	36616_at	DAZ associated protein 2	11.62	down	19	84	H	70.8	29.2
49	33792_at	prostate stem cell antigen	11.62				L	16.9	83.2
50	39500_s_at	hypothetical protein dJ465N24.2.1	11.16			24			

Table 58: Top gene list for Cluster A vs. BC (continued)

Table 59: Top gene list for Cluster B vs. CA

Rank	Affx Num	Gene description	Z-score	Paper		H/L	High%	Low%
				List	Rank			
1	40103_at	villin 2 (ezrin)	605.55	up	1	L	42.7	57.3
2	31497_at	G antigen 2	136.76			L	21.4	78.7
3	32104_i_at	calcium/calmodulin-dependent protein kinase (CaM kinase) II gamma	128.48			L	38.2	61.8
4	41264_at	Homo sapiens mRNA; cDNA DKFZp586F1322 (from clone DKFZp586F1322)	98.03			H	61.8	38.2
5	37348_s_at	thyroid hormone receptor interactor 7	92.13			L	28.1	71.9
6	39775_at	serine (or cysteine) proteinase inhibitor, clade G (C1 inhibitor), member 1	89.83			L	40.5	59.6
7	1086_g_at	CD19 antigen	67.29	up	2	L	46.1	53.9
8	36938_at	N-acylsphingosine amidohydrolase (acid ceramidase)	64.99	down	2	H	50.6	49.4
9	39184_at	transcription elongation factor B (SIII), polypeptide 2 (18kD, elongin B)	47.97			H	73.0	27.0
10	33390_at	CD68 antigen	47.51			H	50.6	49.4
11	1637_at	mitogen-activated protein kinase-activated protein kinase 3	40.61			L	37.1	62.9
12	41577_at	protein phosphatase 1, regulatory (inhibitor) subunit 16B	32.33			L	42.7	57.3
13	40828_at	Rho guanine nucleotide exchange factor (GEF) 7	32.33	up	32	L	39.3	60.7
14	37672_at	ubiquitin specific protease 7 (herpes virus-associated)	30.03	up	10	L	41.6	58.4
15	32774_at	NADH dehydrogenase (ubiquinone) 1 beta subcomplex, 8 (19kD, ASH1)	28.18			L	21.4	78.7
16	38363_at	TYRO protein tyrosine kinase binding protein	25.42	down	22	L	48.3	51.7
17	34573_at	ephrin-A3	25.42			L	25.8	74.2
18	39044_s_at	diacylglycerol kinase, delta (130kD)	24.96	up	17	L	49.4	50.6
19	1519_at	v-ets avian erythroblastosis virus E26 oncogene homolog 2	23.12			L	43.8	56.2
20	1389_at	membrane metallo-endopeptidase (neutral endopeptidase, enkephalinase, CALLA, CD10)	22.20			L	37.1	62.9
21	39866_at	ubiquitin specific protease 22	19.90			L	38.2	61.8
22	33137_at	latent transforming growth factor beta binding protein 4	19.90			L	31.5	68.5
23	35367_at	lectin, galactoside-binding, soluble, 3 (galectin 3)	19.44	down	5	L	46.1	53.9
24	33470_at	KIAA1719 protein	19.44			L	28.1	71.9
25	37325_at	farnesyl diphosphate synthase (farnesyl pyrophosphate synthetase, dimethylallyltransferase, geranyltransferase)	18.98			L	18.0	82.0
26	32174_at	solute carrier family 9 (sodium/hydrogen exchanger), isoform 3 regulatory factor 1	18.52			L	36.0	64.0
27	40281_at	neural precursor cell expressed, developmentally down-regulated 5	18.06			L	41.6	58.4
28	38269_at	protein kinase D2	18.06	up	3	L	42.7	57.3
29	41187_at	myosin regulatory light chain	17.14			H	82.0	18.0

Rank	Affx Num	Gene description	Z-score	Paper		H/L	High%	Low%
				List	Rank			
30	40877_s_at	D15F37 (pseudogene)	17.14			H	51.7	48.3
31	39139_at	signal peptidase complex (18kD)	17.14			L	41.6	58.4
32	210_at	phospholipase C, beta 2	17.14			H	65.2	34.8
33	1179_at	NO_SIF_seq	17.14			H	50.6	49.4
34	36952_at	hydroxacyl-Coenzyme A dehydrogenase/3-ketoacyl-Coenzyme A thiolase/enoyl-Coenzyme A hydratase (trifunctional protein), alpha subunit	16.22			H	83.2	16.9
35	35974_at	lymphoid-restricted membrane protein	16.22	up	36	H	52.8	47.2
36	40134_at	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit f, isoform 2	15.76			L	21.4	78.7
37	37759_at	Lysosomal-associated multispinning membrane protein-5	15.76			L	48.3	51.7
38	34508_r_at	KIAA1079 protein	15.76			L	44.9	55.1
39	31955_at	Finkel-Biskis-Reilly murine sarcoma virus (FBR-MuSV) ubiquitously expressed (fox derived); ribosomal protein S30	14.84			L	41.6	58.4
40	1827_s_at	v-myc avian myelocytomatosis viral oncogene homolog	14.84			L	23.6	76.4
41	37347_at	ESTs, Highly similar to A36870 cell division control protein CKS1 [H.sapiens]	14.38			L	31.5	68.5
42	36111_s_at	splicing factor, arginine/serine-rich 2	14.38	up	13	L	44.9	55.1
43	35835_at	Homo sapiens cDNA FLJ30217 fis, clone BRACE2001709, highly similar to Homo sapiens anaphase-promoting complex subunit 5 (APC5) mRNA	14.38			H	66.5	31.5
44	32510_at	aldo-keto reductase family 7, member A2 (aflatoxin aldehyde reductase)	13.92			L	38.2	61.8
45	34415_at	activin A receptor, type IB	13.46			L	23.6	76.4
46	32051_at	hypothetical protein MGC2840 similar to a putative glucosyltransferase	13.00			L	44.9	55.1
47	40570_at	forkhead box O1A (rhabdomyosarcoma)	12.54			L	27.0	73.0
48	34965_at	cystatin F (leukocystatin)	12.54			L	30.3	69.7
49	37376_at	ORF	12.08			L	44.9	55.1
50	39994_at	chemokine (C-C motif) receptor 1	11.62	down	9	H	50.6	49.4

Table 59: Top gene list for Cluster B vs. CA (continued)

Table 60: Top gene list for Cluster C vs. AB

Rank	Affx Num	Gene description	Z-score	Paper		126	H/L	High%	Low%
				List	Rank				
1	40103_at	villin 2 (ezrin)	650.18	down	2	8	H	50.6	49.4
2	36938_at	N-acylsphingosine amidohydrolase (acid ceramidase)	140.44			1	H	50.6	49.4
3	35755_at	inositol 1,3,4-trisphosphate 5/6 kinase	96.27			99	L	38.2	61.8
4	37348_s_at	thyroid hormone receptor interactor 7	94.89				L	30.3	69.7
5	39184_at	transcription elongation factor B (SIII), polypeptide 2 (18kD, elongin B)	81.55				L	18.0	82.0
6	35367_at	lectin, galactoside-binding, soluble, 3 (galectin 3)	81.55			2	L	38.2	61.8
7	35841_at	polymerase (RNA) II (DNA directed) polypeptide L (7.6kD)	74.19			112	H	55.1	44.9
8	1637_at	mitogen-activated protein kinase-activated protein kinase 3	67.29	up	3	3	L	37.1	62.9
9	40539_at	myosin IXB	62.23				L	15.7	84.3
10	38485_at	NADH dehydrogenase (ubiquinone) 1, subcomplex unknown, 1 (6kD, KFYI)	57.63			75	H	64.0	36.0
11	33768_at	dystrophia myotonica-containing WD repeat motif	52.11				H	80.9	19.1
12	31626_i_at	amine oxidase, copper containing 3 (vascular adhesion protein 1)	50.73				L	24.7	75.3
13	40819_at	RNA binding motif protein 8A	39.69				L	12.4	87.6
14	34573_at	ephrin-A3	39.23				L	31.5	68.5
15	40094_r_at	Lutheran blood group (Aubergier b antigen included)	37.85				L	18.0	82.0
16	36517_at	U2(RNU2) small nuclear RNA auxiliary factor 1 (non-standard symbol)	36.47				H	57.3	42.7
17	40109_at	serum response factor (c-fos serum response element-binding transcription factor)	33.25				H	73.0	27.0
18	39689_at	cystatin C (amyloid angiopathy and cerebral hemorrhage)	32.33			13	L	38.2	61.8
19	37672_at	ubiquitin specific protease 7 (herpes virus-associated)	32.33				L	31.5	68.5
20	40522_at	glutamate-ammonia ligase (glutamine synthase)	31.87				L	49.4	50.6
21	32166_at	Homo sapiens clone 24775 mRNA sequence	31.41			125	L	47.2	52.8
22	39994_at	chemokine (C-C motif) receptor 1	29.10			9	L	37.1	62.9
23	1096_g_at	CD19 antigen	26.80	down	1	7	H	55.1	44.9
24	36952_at	hydroxyacyl-Coenzyme A dehydrogenase/3-ketoacyl-Coenzyme A thiolase/enoyl-Coenzyme A hydratase (trifunctional protein), alpha subunit	22.66				H	61.8	38.2
25	39866_at	ubiquitin specific protease 22	21.74				L	38.2	61.8
26	38368_at	dUTP pyrophosphatase	21.74				L	23.6	76.4
27	1450_g_at	proteasome (prosome, macropain) subunit, alpha type, 4	21.74			54	L	37.1	62.9
28	39827_at	hypothetical protein	21.28				L	49.4	50.6
29	33308_at	glucuronidase, beta	19.90			86	L	39.3	60.7
30	32774_at	NADH dehydrogenase (ubiquinone) 1 beta subcomplex, 8 (19kD, ASH1)	19.90				H	55.1	44.9
31	1034_at	tissue inhibitor of metalloproteinase 3 (Sorsby fundus dystrophy, pseudoinflammatory)	19.90				L	36.0	64.0
32	39139_at	signal peptidase complex (18kD)	19.44			30	L	41.6	58.4
33	35337_at	F-box only protein 7	18.52				H	67.4	32.6
34	38363_at	TYRO protein tyrosine kinase binding protein	18.06	up	4	14	L	43.8	56.2

Rank	Affx Num	Gene description	Z-score	Paper		126	H/L	High%	Low%
				List	Rank				
35	37341_at	glutamate dehydrogenase 1	18.06				L	29.2	70.8
36	32174_at	solute carrier family 9 (sodium/hydrogen exchanger), isoform 3 regulatory factor 1	18.06				L	36.0	64.0
37	40774_at	chaperonin containing TCP1, subunit 3 (gamma)	17.60				H	68.5	31.5
38	39803_s_at	chromosome 21 open reading frame 2	17.60				H	55.1	44.9
39	36630_at	delta sleep inducing peptide, immunoreactor	17.60				L	42.7	57.3
40	40792_s_at	triple functional domain (PTPRF interacting)	16.68				L	36.0	64.0
41	40134_at	ATP synthase, H+ transporting, mitochondrial F0 complex, subunit f, isoform 2	16.68			118	L	34.8	65.2
42	37028_at	protein phosphatase 1, regulatory (inhibitor) subunit 15A	16.68				L	46.1	53.9
43	34161_at	lactoperoxidase	16.68				L	49.4	50.6
44	39044_s_at	diacylglycerol kinase, delta (130kD)	15.76				H	67.4	32.6
45	37351_at	uridine phosphorylase	15.30			69	H	51.7	48.3
46	39795_at	adaptor-related protein complex 2, mu 1 subunit	14.84				L	36.0	64.0
47	37294_at	B-cell translocation gene 1, anti-proliferative	14.84				H	57.3	42.7
48	33821_at	homolog of yeast long chain polyunsaturated fatty acid elongation enzyme 2	14.84				L	43.8	56.2
49	41374_at	ribosomal protein S6 kinase, 70kD, polypeptide 2	14.38				H	51.7	48.3
50	37026_at	core promoter element binding protein	14.38				H	52.8	47.2

Table 60: Top gene list for Cluster C vs. AB (continued)

Table 61: Statistical significance of the prediction for VxInsight clusters

# f gen s	A vs. not-A		B vs. not-B		C vs. n t-C	
	pVal1	pVal2	pVal1	pVal2	pVal1	pVal2
1	0.000096	0.346847	0.000004	0.000010	0.000021	0.000065
2	0.000004	0.016428	0.000000	0.000000	0.000000	0.000000
3	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
4	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
5	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
6	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
7	0.000004	0.031532	0.000001	0.000002	0.000000	0.000000
8	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
9	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
10	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
11	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
12	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
13	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
14	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
15	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
16	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
17	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
18	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
19	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
20	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
21	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
22	0.000004	0.031532	0.000000	0.000000	0.000000	0.000000
23	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
24	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
25	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
26	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
27	0.000021	0.085586	0.000000	0.000000	0.000000	0.000000
28	0.000021	0.037385	0.000000	0.000000	0.000000	0.000000
29	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
30	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
31	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
32	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
33	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
34	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
35	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
36	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
37	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
38	0.000004	0.006823	0.000000	0.000000	0.000000	0.000000
39	0.000001	0.000908	0.000000	0.000000	0.000000	0.000000
40	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
41	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
42	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
43	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
44	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
45	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
46	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
47	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
48	0.000004	0.002288	0.000000	0.000000	0.000000	0.000000
49	0.000001	0.000908	0.000000	0.000000	0.000000	0.000000
50	0.000001	0.000908	0.000000	0.000000	0.000000	0.000000

Table 62: OVA classification results for VxInsight clusters (only with DIFF genes)

# of genes	A vs B C				B vs C A				C vs A B			
	Training		Test		Training		Test		Training		Test	
	Correct	SR	Correct	SR	Correct	SR	Correct	SR	Correct	SR	Correct	SR
1	79	0.89	30	0.81	54	0.61	32	0.86	54	0.61	31	0.84
2	82	0.92	32	0.86	72	0.81	35	0.95	77	0.87	36	0.97
3	84	0.94	31	0.84	76	0.85	35	0.95	79	0.89	35	0.95
4	87	0.98	31	0.84	73	0.82	34	0.92	80	0.90	35	0.95
5	87	0.98	31	0.84	70	0.79	34	0.92	77	0.87	36	0.97
6	88	0.99	31	0.84	76	0.85	35	0.95	77	0.87	36	0.97
7	84	0.94	32	0.86	74	0.83	35	0.95	77	0.87	36	0.97
8	84	0.94	32	0.86	77	0.87	35	0.95	80	0.90	36	0.97
9	84	0.94	32	0.86	77	0.87	35	0.95	80	0.90	36	0.97
10	83	0.93	32	0.86	77	0.87	36	0.97	80	0.90	36	0.97
11	82	0.92	32	0.86	76	0.85	36	0.97	82	0.92	36	0.97
12	83	0.93	32	0.86	78	0.88	36	0.97	82	0.92	36	0.97
13	83	0.93	32	0.86	76	0.85	36	0.97	81	0.91	36	0.97
14	84	0.94	32	0.86	76	0.85	36	0.97	82	0.92	35	0.95
15	84	0.94	32	0.86	75	0.84	36	0.97	82	0.92	36	0.97
16	83	0.93	32	0.86	77	0.87	36	0.97	82	0.92	36	0.97
17	84	0.94	32	0.86	78	0.88	36	0.97	82	0.92	36	0.97
18	84	0.94	32	0.86	78	0.88	36	0.97	82	0.92	36	0.97
19	84	0.94	32	0.86	76	0.85	36	0.97	81	0.91	36	0.97
20	84	0.94	32	0.86	75	0.84	36	0.97	81	0.91	36	0.97
21	83	0.93	32	0.86	76	0.85	36	0.97	82	0.92	36	0.97
22	83	0.93	32	0.86	75	0.84	36	0.97	83	0.93	35	0.95
23	85	0.96	31	0.84	76	0.85	35	0.95	79	0.89	36	0.97
24	85	0.96	31	0.84	78	0.88	36	0.97	79	0.89	36	0.97
25	85	0.96	31	0.84	73	0.82	35	0.95	79	0.89	36	0.97
26	85	0.96	31	0.84	72	0.81	36	0.97	80	0.90	36	0.97
27	85	0.96	31	0.84	75	0.84	35	0.95	81	0.91	36	0.97
28	85	0.96	31	0.84	76	0.85	34	0.92	80	0.90	35	0.95
29	85	0.96	31	0.84	76	0.85	34	0.92	82	0.92	34	0.92
30	85	0.96	31	0.84	76	0.85	34	0.92	81	0.91	34	0.92
31	85	0.96	31	0.84	76	0.85	34	0.92	80	0.90	33	0.89
32	85	0.96	31	0.84	76	0.85	34	0.92	77	0.87	34	0.92
33	85	0.96	31	0.84					79	0.89	35	0.95
34	85	0.96	32	0.86					79	0.89	35	0.95
35	85	0.96	32	0.86					78	0.88	35	0.95
36	84	0.94	33	0.89					81	0.91	35	0.95
37	84	0.94	33	0.89								
38	84	0.94	34	0.92								
39	84	0.94	34	0.92								
40	84	0.94	34	0.92								
41	84	0.94	35	0.95								
42	84	0.94	34	0.92								
43	84	0.94	35	0.95								
44	84	0.94	35	0.95								
45	85	0.96	34	0.92								
46	85	0.96	34	0.92								

REFERENCES FOR SUPPLEMENTARY INFORMATION

1. Becton D, Ravindrinath Y, Dahl GV, Berkow RL, Chang M, Stine K, Behm FG, Raimondi SC, Massey G, Weinstein HJ: A Phase III study of intensive cytarabine (Ara-C) induction followed by cyclosporine (CSA) modulation of drug resistance in de novo pediatric AML; POG 9421. *Blood*. 98, 461a (2001).
2. Dreyer ZE, Steuber CP, Bowman WP, Murray JC, Coppes MJ, Dinndorf P, Camitta B: High risk infant ALL- improved survival with intensive chemotherapy (POG9407). *Proc Am. Soc. Clin. Oncol.* 17, 529a (1998).
3. Frankel LS, Ochs J, Shuster JJ, Dubowy R, Bowman WP, Hockenberry-Eaton M, Borowitz M, Carroll AJ, Steuber CP, Pullen DJ: Therapeutic trial for infant acute lymphoblastic leukemia: the Pediatric Oncology Group experience (POG 8493). *J. Pediatr. Hematol. Oncol.* 19, 35-42 (1997).
4. Lauer SJ, Camitta BM, Leventhal BG, Mahoney D, Shuster J, Keifer G, Pullen J, SteuberCP, Carroll AJ, Kamen B: Intensive alternating drug pairs after remission induction for treatment of infants with acute lymphoblastic leukemia: a Pediatric Oncology Group study (POG8398). *J. Pediatr. Hematol. Oncol.* 20, 229-33 (1998).
5. Ravindrinath Y, Yeager AM, Chang M, Steuber CP, Krischer J, Graham-Pole J, Carroll A, Inoue S, Camitta B, Weinstein HJ: Autologous bone marrow transplantation versus intensive consolidation chemotherapy for acute myeloid leukemia in childhood (POG8821). *N. Engl. J. Med.* 334,1428-34 (1996).
6. Helman, P., Veroff, R., Atlas, S., Willman, C. A Bayesian network classification methodology for gene expression data. (submitted 2003;

available on the worldwide web at
cs.unm.edu/~helman/papers/JCB_Total.pdf).

- 5 7. Pearl, J. Probabilistic reasoning for intelligent systems. Morgan Kaufmann, San Francisco (1988).
8. Heckerman, D., Geiger, D., Chickering, D. Learning Bayesian networks: The combination of knowledge and statistical data. *Machine Learning*. 20, 197-243 (1995).
- 10 9. Duda, R., Hart, P. Pattern classification and scene analysis. John Wiley and Sons, New York. (1973).
- 15 10. Langley, P., Iba, W., Thompson, K. An analysis of Bayesian classifiers. In *Proc. 10th National Conference on Artificial Intelligence* 223-228, AAAI Press. (1992).
- 20 11. Friedman, N., Geiger, D., Goldszmidt, M. Bayesian network classifiers. *Machine Learning*. 29, 131-163 (1997).
- 25 12. Ben-Dor, A., Bruhn, L., Friedman, N., Nachman, I., Schummer, M., & Yakhini, Z. Tissue Classification with Gene Expression Profiles. *J. Comput. Biol.* 7, 559-584 (2000).
- 30 13. Ben-Dor A., Friedman N. and Yakhini Z. Class discovery in gene expression data, In *Proc. Fifth Annual Conference of Computational Biology*, 31-38, ACM Press, New York (2001)
14. Cristianini N. and Shawe-Taylor, J. *An Introduction to Support Vector Machines and other kernel-based learning methods*, Cambridge University Press, Cambridge (2000).

15. Mangasarian O. Generalized Support Vector Machines, Smola A., Barlett P., Scholköpfung B. and Schuurmans C., editors, *Advances in Large Margin Classifiers*, MIT Press, Cambridge, MA. (1999).
- 5 16. Vapnik V. *Statistical Learning Theory*, John Wiley & Sons, New York (1999).
17. Golub T., Slonim D., Tamayo P., Huard C., Caasenbeek J., Collier H., Loh M., Downing J., Caligiuri M., Bloomfield M., and Lander E.
10 Molecular classification of cancer: class discovery and prediction by gene expression monitoring, *Science* 286, 531-537 (1999).
18. Guyon I., Weston J., Barnhill S. and Vapnik V. 2002, Gene Selection for Cancer Classification using Support Vector Machines, *Machine Learning* 46, 389-422.
15
19. Ramaswamy S., Tamayo P., Rifkin R., Mukherjee S., Yeang C., Angelo M., Ladd C., Reich M., Latulippe E., Mesirov J., Poggio T., Gerald W., Loda M., Lander E. and Golub T. Multiclass cancer diagnosis using tumor gene expression signatures, *Proc. Natl. Acad. Sci.* 98, 15149-15154 (2002).
20
20. Ambriose S. and McLachlan G. Selection Bias in gene extraction on the basis on microarray gene expression data. *Proc. Natl. Aca. Sci.* 99, 6562-6566 (2002).
25
21. The MathWorks, Inc. *MATLAB User's Guide*, Natick, MA 01760 (1992).
- 30 22. Mangasarian O. and Musicant D. Lagrangian Support Vector Machines, *Journal of Machine Learning Research.* 1,161-177 (2001).

23. Michael T. Brown and Lori R. Wricker, Discriminant Analysis. In: *Handbook of Applied Multivariate Statistics and Mathematical Modeling*. Academic, New York. Affymetrix Statistical Algorithms Reference Guide. Affymetrix Inc. (2001).
- 5
24. Zadeh L.A. Fuzzy logic and its application to approximate reasoning. *Information Processing*. 74, 591-594 (1974).
25. Nguyen, H.T. and Walker, E.A. A First Course in Fuzzy Logic. CRC
10 press (1997).
26. Woolf, P.J. and Wang, Y. A fuzzy logic approach to analyzing gene
expression data. *Physiol Genomics*. 3, 9-15. (2000).
- 15 27. Mendel, J. M. *Fuzzy logic systems for engineering: a tutorial*.
Proceedings of the IEEE, 83, 345-377 (1995).
28. Wang, L. Adaptive Fuzzy Systems and Control. Prentice-Hall (1994).
- 20 29. Moore, D.S. The Basic Practice of Statistics. W.H. Freeman and Co.
(2000).
30. Wang, X., Atlas, S., Willman, C. L., and Li, B.L. Adaptive Neuro-Fuzzy
Clustering Analysis of Gene Microarray Data. Preprint. Univ. of New
25 Mexico. (2002).
31. Liu, H., Motoda, H., and Dash, M. A monotonic measure for optimal
feature selection. In Proceedings of European Conference on Machine
Learning, pp 101-106. (1998).
- 30 32. Siedlecki, W. and Sklansky, L. A not on genetic algorithms for large-
scale feature selection. *Pattern Recognition Letters*. 10, 335-347 (1989).

33. Moore, A. and Lee, M. Efficient algorithms for minimizing cross validation error. In Proceedings of 11th International Machine Learning Conference. Morgan Kaufmann. (1994).
- 5 34. Mathworks User's Guide of Fuzzy Logic Toolbox. The Mathworks Inc. (2000).
35. Casella, G. & Berger, R. L. *Statistical Inference*. Belmont, Calif.:Duxbury Press. (2002).
- 10 36. Agresti, A, *Categorical Data Analysis, 2nd Ed.*, Hoboken:John Wiley & Sons. (2002).
37. The SAS System for Windows, Release 8.02, SAS Institute, Inc. (2001).
- 15 38. Lehmann, E. L. *Testing Statistical Hypotheses*, Belmont, CA: Wadsworth & Brooks. (1991).
39. Eisen, M. B., Spellman, P. T., Brown, P. O., and Botstein, D. Cluster analysis and display of genome-wide expression patterns. *Proc. Natl. Acad. Sci. USA* 95, 14863-14868 (1998).
- 20 40. Jolliffe, I.T. *Principal Component Analysis*. Springer-Verlag (1986).
41. Kirby, M. Geometric Data Analysis. John Wiley & Sons (2001).
- 25 42. Trefethen, L. & Bau, D. *Numerical Linear Algebra*. SIAM, Philadelphia (1997).
- 30 43. Davidson, G. S., Wylie, B. N., & Boyack, K. W. Cluster Stability and the Use of Noise in Interpretation of Clustering. *Proc. IEEE Information Visualization 2001*, 23-30 (2001).

44. Davidson, G. S., Hendrickson, B., Johnson, D. K., Meyers, C. E., & Wylie, B. N. Knowledge mining with VxInsight: Discovery Through Interaction. *Journal of Intelligent Information Systems*. 11, 259-285 (1998).
- 5
45. Kim, S. K., Lund, J., Kiraly, M., Duke, K., Jiang, M., Stuart, J. M., Eizinger, A., Wylie, B. N., and Davidson, G. S. A gene expression map for *Caenorhabditis elegans*. *Science* 293, 2087-2092 (2001).
- 10
46. Werner-Washburne, M., Wylie, B., Boyack, K., Fuge, E., Galbraith, J., Fleharty, M., Weber, J., Davidson, G.S. Concurrent analysis of multiple genome-scale datasets. *Genome Research*. 12, 1564-1573 (2002).
- 15
47. Efron, B. Bootstrap methods—"another look at the jackknife" *Ann. Statist.* 7, 1-26 (1979).
- 20
48. Hjorth, J.S. *Urban Computer Intensive Statistical Methods, Validation model selection and bootstrap*, ISBN 0412491605, Chapman & Hall, 2-6 Boundary Row, London SE1 8HN, UK. (1994).
- 25
49. Slonim, D.K., Tamayo, P., Mesirov, J.P., Golub, T.P., and Lander, E.S. Class prediction and discovery using gene expression data. In: *Proc. 4th Annual International Conf. on Computational Molecular Biology (RECOMB)* pp. 263-272, Universal Academy Press, Tokyo, Japan. (1999).
- 30
50. Li, L., Weinberg, C.R., Darden, T.A., and Pedersen, L.G. Gene selection for sample classification based on gene expression data: study of sensitivity to choice of parameters of the GA/KNN method. *Bioinformatics*, 17, 1131-1142 (2001).
51. Li, L., Darden, T.A., Weinberg, C.R., Levine, A.J., and Pedersen, L.G. Gene assessment and sample classification for gene expression data

using a genetic algorithm/k-nearest neighbor method. *Combinatorial Chemistry and High Throughput Screening*, 4, 727-739 (2001).

52. Hastie, T., Tibshirani, R., and Friedman, J. *The Elements of Statistical Learning*. Springer:New York. (2001).

EXAMPLE XIV

Heterogeneity of Gene Expression Profiles in *MLL*-Associated Infant Leukemia: Identification of Distinct Expression Profiles and Novel Therapeutics Targets

Summary

Translocations involving the *MLL* (*ALL-1*, *HRX*, *Htrx-1*) gene at chromosome band 11q23 are the most common cytogenetic abnormality seen in infant leukemia. While there is evidence that *MLL*-associated chromosomal rearrangements carry a poorer prognosis, the pathogenesis and unique gene expression for each *MLL* rearrangement remain largely undefined. Using oligonucleotide arrays (Affymetrix U95Av2) and both unsupervised and supervised analysis methods we derived comprehensive gene expression profiles from a retrospective cohort of 126 infant cases registered to NCI-sponsored clinical trials. Fifty-three of those cases had *MLL* rearrangements with several partner genes (*AF4*, *ENL*, *AF10*, *AF9* and *AF1Q*). We used class identification methods (Bayesian networks, Support Vector Machines and Discriminant Analysis) to determine genes with common patterns of expression across all the *MLL* cases as well as genes that were uniquely expressed and distinguishing of each *MLL* translocation variant. However, class discovery tools suggested that the *MLL*-associated profiles were quite heterogeneous among different translocation variants and were dominated by three differential expression patterns. Interpretation of our data indicated that infant *MLL* is an entity comprising several intrinsic biologic classes not precisely predicted by current standards of morphology, immunophenotyping, or cytogenetics. Consideration of such class-membership could improve classification schemes and reveal potential therapeutic targets for *MLL*-associated leukemias.

Introduction

In Example XIII, we analyzed the gene expression profiles in samples of 126 infant acute leukemia patients. Three inherent biologic subgroups were identified. These groups were not well defined by traditional cell types (AML vs. ALL) or cytogenetic (*MLL* vs. not) labels. Instead, they reflected different etiologic events with biological and clinical relevance. The distribution of the *MLL* infant cases between those "etiology-driven" clusters is the focus of this study.

Materials and Methods

For this study we analyzed 126 diagnostic bone marrow samples from patients with acute leukemia who were aged < 1 year at diagnosis. In each case, the percentage of blast was >80%. The cohort was designed from cases registered to NCI-sponsored Infant Oncology Group/Children's Oncology Group treatment trials number 8398, 8493, 8821, 9107, 9407 and 9421. Of the 126 cases, 78 (62%) were acute lymphocytic leukemia (ALL) and 48 (38%) were acute myeloid leukemia (AML) by standard morphological and immunophenotypic criteria. Fifty-three (42%) cases had translocations involving the *MLL* gene (chromosome segment 11q23). An average of 2×10^7 cells were used for total RNA extraction with the Qiagen RNeasy mini kit (Valencia, CA). The yield and integrity of the purified total RNA were assessed using the RiboGreen assay (Molecular Probes, Eugene, OR) and the RNA 6000 Nano Chip (Agilent Technologies, Palo Alto, CA), respectively. Complementary RNA (cRNA) target was prepared from 2.5 μ g total RNA using two rounds of Reverse Transcription (RT) and In Vitro Transcription (IVT). Following denaturation for 5 min at 70°C, the total RNA was mixed with 100 pmol T7- (dT) 24 oligonucleotide primer (Genset Oligos, La Jolla, CA) and allowed to anneal at 42°C. The mRNA was reverse transcribed with 200 units Superscript II (Invitrogen, Grand Island, NY) for 1 hr at 42°C. After RT, 0.2 vol 5X second strand buffer, additional dNTP, 40 units DNA polymerase I, 10 units DNA ligase, 2 units RnaseH (Invitrogen) were added and second strand cDNA synthesis was performed for 2 hr at 16°C. After T4 DNA polymerase (10 units), the mix was incubated an additional 10 min at 16°C. An equal

volume of phenol:chloroform:isoamyl alcohol (25:24:1) (Sigma, St. Louis, MO) was used for enzyme removal. The aqueous phase was transferred to a microconcentrator (Microcon 50, Millipore, Bedford, MA) and washed/concentrated with 0.5 ml DEPC water until the sample was concentrated to 10-20 ul. The cDNA was then transcribed with T7 RNA polymerase (Megascript, Ambion, Austin, TX) for 4 hr at 37°C. Following IVT, the sample was phenol:chloroform:isoamyl alcohol extracted, washed and concentrated to 10-20ul. The first round product was used for a second round of amplification which utilized random hexamer and T7- (dT) ₂₄ oligonucleotide primers, Superscript II, two RNase H additions, DNA polymerase I plus T4 DNA polymerase finally and a biotin-labeling high yield T7 RNA polymerase kit (Enzo Diagnostics, Farmingdale, NY). The biotin-labeled cRNA was purified on Qiagen RNeasy mini kit columns, eluted with 50ul of 45°C RNase-free water and quantified using the RiboGreen assay. Following quality check on Agilent Nano 900 Chips, 15ug cRNA were fragmented following the Affymetrix protocol (Affymetrix, Santa Clara, CA). The fragmented RNA was then hybridized for 20 hours at 45°C to HG_U95Av2 probes. The hybridized probe arrays were washed and stained with the EukGE_WS2 fluidics protocol (Affymetrix), including streptavidin phycoerythrin conjugate (SAPE, Molecular Probes, Eugene, OR) and an antibody amplification step (Anti-streptavidin, biotinylated, Vector Labs, Burlingame, CA). HG_U95Av2 chips were scanned at 488 nm, as recommended by Affymetrix. The expression value of each gene was calculated using Affymetrix Microarray Suite 5.0 software.

25

Data Presentation and Exclusion Criteria

Criteria used as quality controls included: total RNA integrity, cRNA quality, array image inspection, B2 oligo performance, and internal control genes (GAPDH value greater than 1800). Of the initial cohort of 142 infant acute leukemia cases, 126 were finally part of this study.

30

Data Analysis

Affymetrix MAS 5.0 statistical analysis software was used to process the raw microarray image data for a given sample into quantitative signal values and associated present, absent or marginal calls for each probe set. A filter was then applied which excluded from further analysis all Affymetrix "control" genes (probe sets labelled with AFFX_ prefix), as well as any probe set that did not have a "present" call at least in one of the samples. This filtering step reduced the number of probe sets from 12625 to 8414, resulting in a matrix of 8,414 x 126 signal values. Our Bayesian classification and VxInsight clustering analyses omitted this step; choosing instead to assume minimal *a priori* gene selection, as described in Helman *et al.*, 2002 and Davidson *et al.*, 2001. The first stage of our analysis consisted of a series of binary classification problems defined on the basis of clinical and biologic labels. The nominal class distinctions were ALL/AML, MLL/not-MLL, and achieved complete remission CR/not-CR. Additionally, several derived classification problems were considered based on restrictions of the full cohort to particular subsets of the data (such as the *VxInsight* clusters). The multivariate supervised learning techniques used included Bayesian nets (Helman *et al.*, 2002) and support vector machines (Guyon *et al.*, 2002). The performance of the derived classification algorithms was evaluated using fold-dependent leave-one-out cross validation (LOOCV) techniques. These methods allowed the identification of genes associated with remission or treatment failure and with the presence or absence of translocations of the MLL gene across the dataset.

In order to identify potential clusters and inherent biologic groups, a large number of clinical co-variables were correlated with the expression data using unsupervised clustering methods such as hierarchical clustering, principal component analysis and a force-directed clustering algorithm coupled with the VxInsight visualization tool. Agglomerative hierarchical clustering with average linkage (similar to Eisen *et al.*, 1998) was performed with respect to both genes and samples, using the MATLAB (The Mathworks, Inc.), MatArray toolbox, as well as the native MATLAB statistics toolbox. The data for a given gene was first normalized by subtracting the mean expression value computed across all patients, and dividing by the standard deviation. The distance metric used for

the hierarchical clustering was one minus Pearson's correlation coefficient. This metric was chosen to enable subsequent direct comparison with the VxInsight cluster analysis, which is based on the *t*-statistic transformation of the correlation coefficient (Davidson *et al.*, 2001).

5 The second clustering method was a particle-based algorithm implemented within the VxInsight knowledge visualization tool. In this approach, a matrix of pair similarities is first computed for all combinations of patient samples. The pair similarities are given by the *t*-statistic transformation of the correlation coefficient determined from the normalized expression
10 signatures of the samples (Davidson *et al.*, 2001). The program then randomly assigns patient samples to locations (vertices) on a two dimensions graph, and draws lines (edges) linking each sample pair, assigning each edge a weight corresponding to the pairwise *t*-statistic of the correlation. The resulting two-dimensional graph constitutes a candidate clustering. To determine the optimal
15 clustering, an iterative annealing procedure is followed. In this procedure a 'potential energy' function that depends on edge distances and weights is minimized by following random moves of the vertices (Davidson *et al.*, 1998, 2001). Once the 2D graph has converged to a minimum energy configuration, the clustering defined by the graph is visualized as a 3D terrain map, where the
20 vertical axis corresponds to the density of samples located in a given 2D region. The resulting clusters are robust with respect to random starting points and to the addition of noise to the similarity matrix, evaluated through effects on neighbour stability histograms (Davidson *et al.*, 2001).

25 *Results*

Expression profiling demonstrates heterogeneity across infant MLL cases

 The determine the variations in gene expression profiles of infant leukemia cases involving different *MLL* rearrangements, 126 infant leukemia cases registered to NCI-sponsored Infant Oncology Group/Children's Oncology
30 Group treatment trials were studied using oligonucleotide microarrays containing 12,625 probe sets (Affymetrix U95Av2 array platform). Of the 126 cases, fifty-three (42%) cases had translocations involving the *MLL* gene

(chromosome segment 11q23). The distribution of the *MLL* cytogenetic abnormalities across this data set is provided in Table 63.

Table 63. Distribution of *MLL* Cytogenetic Abnormalities in the Infant

5 **Cohort**

<i>MLL Translocation</i>		<i>Total # of Cases</i>	
		<i>in Infant Cohort</i>	<i>ALL</i>
			<i>AML</i>
10	t(4;11)	29	28
	t(11;19)	9	7
	t(10;11)	4	2
	t(1;11)	4	2
	t(9;11)	4	1
15	Other <i>MLL</i>	3	1
	Not <i>MLL</i>	42	26
	Unknown	31	11
			20

20 The initial examination of the data was accomplished using the force
directed clustering algorithm coupled with the visualization tool, (Davidson *et*
al., 1998; 2001). When applied to the infant cohort, this particle-based
clustering algorithm demonstrated the existence of three well-separated groups
of patients that displayed similar patterns of gene expression (Fig. 10) These
25 major clusters were statistically robust and internally consistent as demonstrated
by linear discrimination analysis with fold-dependent leave one out cross-
validation (LOOCV). Further analysis demonstrated that the clusters could not
be completely explained by the traditional diagnostic parameters (morphology:
ALL vs. AML, or cytogenetics: *MLL* rearrangement vs. not), implying that the
30 intrinsic biology may not be driven by these variables.
Further analysis suggested an association between the three clusters and
different leukemogenic mechanisms (previously submitted data), called
hereafter "*stem cell-like*", "*lymphoid*" and "*myeloid*"/"*environmental*". *MLL*

cases were seen in each of the mentioned patient clusters (Fig. 13). The *MLL* cases in the "*stem cell-like*" cluster (Cluster A, n=20) were primarily t(4;11) (n=7), as well as two cases with t(10;11) and one with t(11;19). The "*lymphoid*" cluster (Cluster B, n=52) included only one AML case and contained a large number of t(4;11) (n=21) cases as well as four cases with t(11;19), one case with t(10;11), and one case with t(1;11). Finally, the "*myeloid*" cluster (Cluster C, n=54) was predominantly AML but contained twelve cases with an ALL label that nonetheless had a more "*myeloid*" pattern of gene expression. This cluster included some *MLL* cases with t(4;11), all the t(9;11), some t(11;19), and t(X;11). It has been suggested that in contrast to ALL, AML patients with *MLL* rearrangements do not tend to co-express lymphoid -and myeloid-associated antigens simultaneously on leukemic blasts and have outcomes similar to those without the gene rearrangements (Tien, 2000). Our data supports this view, since roughly the same frequencies of long-term remission (30%) and failures (70%) were observed in the "*myeloid*" cluster in patients irrespective of *MLL* translocations.

An important finding of the present study is that two very distinct groups of gene expression profiles could be identified across cases with the same t(4;11) rearrangement (*VxInsight* clusters A and B). Using ANOVA, a gene list that characterizes the t(4;11) groups within the infant clusters A and B was derived (Fig. 15). There is a considerable degree of overlap between the cluster A-characterizing genes and those that distinguish the t(4;11) cases in this group (previously submitted data). Cluster A was typified by genes of particular interest in signal transduction (EFNA3, B7 protein, Cytokeratin type II, latent transforming growth factor beta binding protein 4, Contactin 2 axonal, and Erythropoietin receptor precursor), transcription regulation (Integrin α 3 (ITGA3), Ataxin 2 related protein (A2LP) and Heat-shock transcription factor 4, (HSF4)) and cell-to-cell signaling (Myosin-binding protein C slow-type). Although most useful in the separation of the cluster A cases, these genes seem to be separating the t(4;11) cases in this group as well.

Gene expression patterns of different MLL translocations

The second method used in our analysis was aimed at uncovering sets of genes that characterized each one of the *MLL* translocations. The process of defining the best set of discriminating genes was accomplished using supervised learning techniques such as Bayesian Networks, Linear Discriminant Analysis and Support Vector Machines (SVM) (Reviewed in Orr, 2002). In contrast with unsupervised methods, supervised learning methods learn "known classes", creating classification algorithms that may undercover interesting and novel therapeutic targets. Our characterization of the gene expression profiles per *MLL* variant and the genes involved in these translocations accomplished using supervised learning techniques is shown in Fig. 16. These genes represent novel diagnostic and therapeutic targets for *MLL*-associated leukemias.

Gene expression profiles characteristic of the t(4;11) and other *MLL* translocations are shown in Figs. 17 and 18 (Fig. 17: Bayesian Network analysis, Support Vector Machines analysis, Fuzzy Logics and Discriminant Analysis; Fig. 18: ANOVA from the *VxInsight* program). The different methods allowed the classification of unknown samples within each of the groups with accuracy rates higher than 90%, as calculated by fold dependent leave-one-out cross validation. This data analysis of gene expression conditioned on karyotype generated distinct case clustering, supporting that unique gene expression "signatures" identify defined genetic subsets of infant leukemia. This confirms recently published data (Armstrong et al, 2002), which revealed that the *MLL* infant leukemia cases are characterized by specific gene expression profiles. However, while groups of genes uniquely associated with the *MLL* cases can be identified using supervised learning techniques, infant *MLL* leukemia seems to be an entity comprised of several intrinsic biologic clusters not precisely predicted by current standards of morphology, immunophenotyping, or cytogenetics.

Expression levels of FLT3 across various MLL translocations

Expression levels of the FMS-related tyrosine kinase 3 (*FLT3*) gene were analyzed across different *MLL* translocations. *FLT3*, a member of the receptor tyrosine kinase (RTK) class III, is preferentially expressed on the

surface of a high proportion of acute myeloid leukemia (AML) and B-lineage acute lymphocytic leukemia (ALL) cells in addition to hematopoietic stem cells, brain, placenta and liver (Kiyoe, 2002). Within *MLL* subgroups *FLT3* is variable. The expression levels for this gene were differentially higher in
5 t(4;11), t(11;19), t(9;11) and other *MLL* translocations (Fig. 14)). However, *MLL* subgroups such as t(1;11) and t(10;11) had similar expression of *FLT3* compared to not *MLL* cases, suggesting that the various *MLL* translocations may exert differential influence on the *FLT3* expression levels. This may add arguments to the previously proposed potential problems in the clinical use of
10 *FLT3* inhibitors for leukemia treatment (Gilliland et al, 2002).

Discussion

Gene expression profiling of our infant *MLL* leukemia cases revealed new insights into infant leukemia classification that may increase our
15 understanding of the pathogenesis and hence, treatment options for this disease.

While groups of genes uniquely associated with each *MLL* translocation variant can be identified using supervised learning techniques (as previously shown by others), infant acute *MLL* leukemia seems to be an entity comprised of several intrinsic biologic clusters not precisely predicted by current standards
20 of morphology, immunophenotyping, or cytogenetics. Unsupervised analysis demonstrated that gene expression in specific *MLL* rearrangements varied significantly amongst the three infant groups. As these intrinsic clusters appeared to relate to distinct subtypes of infant leukemia, the various *MLL* translocations may represent a critical secondary transforming event for each
25 biological group, conferring more defined tumor phenotypes. Alternatively, *MLL* translocations may be permissive for further genetic rearrangements that will strongly influence and define differential gene expression patterns. Our findings of heterogeneity of gene expression within and between *MLL* subtypes differ from previous reports suggesting more homogeneous gene
30 expression (Armstrong, 2002). This probably reflects mainly the larger number of cases available to us for analysis. However, rigorous exclusion of unsatisfactory samples was also critical for the successful interpretation of the data.

Particular genes that can be selected by supervised methods as characterizing cases with *MLL* translocations, in the current study the presence or absence of *MLL* rearrangements did not define a distinct leukemia class during unsupervised learning analysis of the gene expression patterns of these

5 infant patients. Despite the fact that supervised analysis of the microarray data can successfully segregate patients defined by traditional methods such as immunophenotyping and cytogenetics, results from these techniques are most useful in the identification of unanticipated similarities and diversities in individual patients and thus may be useful in augmenting risk-group

10 stratification in the future. Further studies to enhance the ability to classify infant *MLL* subtypes according to shared pathways of leukemic transformation will have important implications for the development of new therapeutic approaches.

REFERENCES

- Armstrong, S.A., Staunton, J.E., Silverman, L.B., Pieters, R., den Boer, M.L., Minden, M.D., Sallan, S.E., Lander, E.S., Golub, T.R., Korsmeyer, S.J. MLL translocations specify a distinct gene expression profile that distinguishes a unique leukemia. *Nat Genet* 2002 Jan;30(1):41-7
- Chen C. S., Sorensen P. H. B., Domer P. H., Reaman G. H., Korsmeyer S. J., Heerema N. A., Hammond G. D., Kersey J. H. Molecular-rearrangements on chromosome-11q23 predominate in infant acute lymphoblastic-leukemia and are associated with specific biologic variables and poor outcome. *Blood*. 81, 2386-2393 (1993).
- Davidson, G. S., Wylie, B. N., and Boyack, K. W. Cluster stability and the use of noise in interpretation of clustering. *Proc. IEEE Information Visualization 2001*, 23-30 (2001).
- Davidson, G. S., Hendrickson, B., Johnson, D. K., Meyers, C. E., & Wylie, B. N. Knowledge mining with VxInsight: Discovery through interaction. *J. Int. Inf. Syst.* 11, 259-285 (1998).
- Efron, B. Bootstrap methods—"another look at the jackknife" *Ann. Statist.*,7, 1-26 (1979).
- Ernst P., Wang J., Korsmeyer S.J. The role of MLL in hematopoiesis and leukemia. *Curr. Opin. Hematol.* 9, 282-287 (2002).
- Felix, C., Lange, B. Leukemia in infants. *The Oncologist*. 4, 225-240 (1999).
- Gilliland, D.G., Griffin, J.D. Role of FLT3 in leukemia. *Curr Opin Hematol.* 9, 274-81. (2002)
- Gu, Y.; Nakamura, T.; Alder, H.; Prasad, R.; Canaani, O.; Cimino, G.; Croce, C. M.; Canaani, E. The t(4;11) chromosome translocation of human acute leukemias fuses the ALL-1 gene, related to *Drosophila trithorax*, to the AF-4 gene. *Cell* 71, 701-708 (1992).
- Hjorth, J.S. *Urban Computer Intensive Statistical Methods, Validation model selection and bootstrap* , ISBN 0412491605, Chapman & Hall, 2-6 Boundary Row, London SE1 8HN, UK. (1994).
- Kiyoi, H., Naoe, T. FLT3 in human hematologic malignancies. *Leuk*

Lymphoma. 43, 1541-7 (2002).

Orr, M.S., Scherf, U. Large-scale gene expression analysis in molecular target discovery. *Leukemia*. 16:473-7 (2002). Review.

Parry, P.; Djabali, M.; Bower, M.; Khristich, J.; Waterman, M.;
5 Gibbons, B.; Young, B. D.; Evans, G. Structure and expression of the human trithorax-like gene 1 involved in acute leukemias. *Proc. Nat. Acad. Sci.* 90, 4738-4742 (1993).

Rowley, J. D. The critical role of chromosome translocation in human genetics. *Annu. Rev. Genet.* 32, 495-519, (1998).

10 Sorensen P. H. B., Chen C. S., Smith F. O., Arthur D. C., Domer P. H., Bernstein I. D., Korsmeyer S. J., Hammond G. D., Kersey J. H. Molecular-rearrangements of the *MLL* gene are present in most cases of infant acute myeloid-leukemia and are strongly correlated with monocytic or myelomonocytic phenotypes. *J. Clin. Investig.*, 93, 429-437 (1994).

15 Strick, R., Strissel, P., Borgers, S., Smith, S., Rowley, S. Dietary bioflavonoids induce cleavage in the *MLL* gene and may contribute to infant leukemia *Proc. Natl. Acad. Sci. USA.* 97, 4790-4795 (2000).

Tien, H.F., Hsiao, C.H., Tang, J.L., Tsay, W., Hu, C.H., Kuo, Y.Y., Wang, C.H., Chen, Y.C., Shen, M.C., Lin, D.T., Lin, H.K., Lin, K.S.
20 Characterization of acute myeloid leukemia with *MLL* rearrangement: no increase in the incidence of coexpression of lymphoid-associated antigens on leukemic blasts. *Leukemia*. 14, 1025-1030 (2000).

The complete disclosure of all patents, patent applications, and publications,
25 and electronically available material (including, for example, nucleotide sequence submissions in, e.g., GenBank and RefSeq, and amino acid sequence submissions in, e.g., SwissProt, PIR, PRF, PDB, and translations from annotated coding regions in GenBank and RefSeq) cited herein are incorporated by reference. The foregoing detailed description and examples have been given
30 for clarity of understanding only. No unnecessary limitations are to be understood therefrom. The invention is not limited to the exact details shown and described, for variations obvious to one skilled in the art will be included within the invention defined by the claims.